For Release to Evening Papers of Saturday, December 6, 1930

REPORT OF THE CHIEF OF THE BUREAU OF ENTOMOLOGY

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 25, 1930.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1930.

Respectfully,

C. L. MARLATT,
Entomologist and Chief of Bureau.

HON. ARTHUR M. HYDE,
Secretary of Agriculture.

INTRODUCTION

The work of the Bureau of Entomology is distributed among the following 10 divisions: Deciduous-Fruit Insects, Cereal and Forage Insects, Truck-Crop Insects, Cotton Insects, Insects Affecting Tropical, Subtropical, and Ornamental Plants, Insects Affecting Forest and Shade Trees, Insects Affecting Stored Products, Insects Affecting Man and Animals, Bee-Culture Investigations, Taxonomy and Interrelations of Insects.

This work is being conducted at 113 different field stations located in 36 States. There are additional stations in Alaska, Hawaii, the Canal Zone, and in seven foreign countries. All but one of the foreign stations are concerned with the collection of parasitic and beneficial insects to be imported into the United States to aid in the biological control of certain recently introduced pests.

The Division of Taxonomy and Interrelations of Insects is concerned with such basic work as the scientific study of insects from the standpoint of determination and classification, and with other related technical investigations. Bee culture represents an important industry and is studied to secure better protection from any preventable hazards—diseases and parasites of bees, winter losses, etc.—and to increase production. The other eight divisions of the bureau cover research in the field of control of important farm, garden, and forest insect pests, and insects having any important economic relationship with man and animals. Much of the work in these several fields of research has to do either with native or long-established insect pests, as to many of the more important subjects, and is maintained from year to year for the purpose of improving methods of control or modifying them to meet new conditions in different sections of the country. The practical results of such continuing

work in this field, while not spectacular or of special news value, nevertheless represent probably the major yearly output of the bureau. New subjects for investigation are, however, constantly arising, concerning either native insects assuming new and harmful relations or recently introduced pests, and these—and particularly the latter—frequently develop perhaps a much larger public interest for the time being and are therefore given special prominence in annual reports.

The annual budget for the bureau reflects increases both as to such old and continuing subjects and new fields of work. As a matter of record, the important increases for the fiscal year under report may be summarized as follows.

NEW SUBJECTS

For importation and establishment of parasites of the oriental fruit moth, $15,000; for the introduction and establishment in Cuba of black-fly parasites imported from the Orient, in cooperation with the Cuban Department of Agriculture, $6,000; for investigating the strawberry-root aphid in North Carolina, $2,000; for the collection near Mexico City of dipterous parasites of the Mexican bean beetle, and for importing and establishing these parasites in this country, $5,000; for investigating leaf hoppers affecting alfalfa, clover, and other forage legumes, particularly for initiating investigations of the rôle of leaf hoppers in the transmission of alfalfa yellows, $3,000; for devising methods of disposing of waste from gins and oil mills as a means of preventing the spread of the pink bollworm and Thurberia weevil, $6,000; for the importation and establishment of promising parasites of the pink bollworm recently found in Kenya Colony, East Africa, $10,000; and for investigations on eye gnats in California, $12,000. Total, $59,000.

INCREASES AS TO OLDER OR CONTINUING SUBJECTS

For study of methods of disinfecting imported and domestic nursery stock and other plant products to facilitate insect quarantine operations, $3,000; for investigating bulb insects in the East, $7,500; for the investigation of hydrocyanic-acid gas fumigation as a means of controlling scale pests of citrus and other fruits in southern California, $4,160; for working out methods of control of the wireworms affecting miscellaneous truck crops in Idaho and Washington, $5,000; for expansion of work on the sugar-beet leaf hopper in Idaho, $18,000; for expansion of work on the sugar-beet leaf hopper in the intermountain and west coast region, the work centering in the laboratory at Twin Falls, Idaho, $79,374; for the investigation of tree-killing bark beetles in the Western States, $9,640; for control of the Mormon cricket in northwestern Colorado, $8,000; for the importation of parasites of the European corn borer, $40,000; for investigation of insect pests affecting flour, particularly the flour intended for export, to take care of a serious emergency which has arisen in this field as the result of stringent requirements of foreign importers of flour, $17,000; and for taxonomic studies of tree-killing bark beetles and weevils injurious to plants and plant products, $5,000. Total, $196,674. Total increases, $255,674.

DECREASES

Gipsy and brown-tail moth project	$1,000
Insects affecting cattle	100
Bee culture	120
Total decreases	1,220
Total net increases	254,454

The work, so far as it has been possible to institute it under these new subjects, and also as to old work, will be indicated in the reports under the different divisions concerned.

DECIDUOUS-FRUIT INSECTS

Investigations of deciduous-fruit insects have been carried out, as heretofore, under the direction of A. L. Quaintance.

JAPANESE BEETLE

General summer scouting as well as quantitative larval surveys conducted in certain selected areas during 1929 served to confirm the earlier-expressed opinion that the Japanese beetle is decreasing in the older occupied areas and increasing in those more recently invaded. The decrease in 1929 in the Moorestown-Riverton district reached a point which caused repeated inquiries to be made by the citizens as to what had become of the beetles. In localities more remote from the original center of spread, on the other hand, the infestation in 1929 increased to proportions comparable to conditions which existed in the Riverton area during the period 1920 to 1925.

This belief was further confirmed by extended larval scouting during the season of 1930. In connection with the surveys it has been observed that in rolling country larvae are likely to be much more abundant in low-lying, poorly drained situations, a fact of which advantage may be taken in control operations.

BIOLOGY

As during earlier years, information on questions relating to the biology and behavior of the beetle in its various stages is being secured and utilized wherever possible in repressive work. Recent studies indicate that pupation is either completely inhibited or excessively prolonged when temperatures fail to reach 65° F., no matter how far advanced the larvae may be at the time of entering winter hibernation. Studies have been made as to the time required for the development of the egg and pupa under variable temperatures as compared with constant temperatures. The results indicate that, within the limits of experimental error, the time required for development under a set of variable temperatures will fall close to, or coincide with, the time taken at a constant temperature coinciding with the mean of the variable temperatures. However, this general rule was found to apply only in those cases where the range of the variable temperatures lay above the temperature where development begins. In view of the fact that by far the greater part of the life cycle of the Japanese beetle is spent in the soil, the studies in the correlation of atmospheric and soil temperatures have been stressed as in previous years. These data may be useful in computing the time of

appearance of the successive stages of the insect for different soils and for different parts of the country. Thus, based on the knowledge that pupation does not ordinarily take place until a temperature of about 65° is reached, maps were drawn showing the zone within which the beetles, if established, would probably first put in appearance. During the spring of 1930 these maps were utilized by the scouting service of the Plant Quarantine and Control Administration, and to date the results are in fairly close agreement with those anticipated.

SOIL-INSECTICIDE INVESTIGATIONS

During the fiscal year research work in this field has been carried on largely with a view to developing new methods and improving existing procedures for destroying the immature stages of the Japanese beetle in the soil about the roots of many different kinds of nursery plants. The experimental work to determine the efficiency of immersing the subterranean portion of dormant nursery plants in water at a temperature of 112° F., to destroy the immature stages of the beetle, has been practically completed, and it is now possible to recommend the treatment as a quick, simple, and effective method for use in the case of certain herbaceous plants and deciduous shrubs. It has been successfully demonstrated that 3-year-old plants of *Azalea indica* can be fumigated with carbon disulphide. The plants are put in a special fumigating tank in such a manner that the top is protected from the gas by being immersed in water while the roots are exposed to the insecticidal vapor. Experiments are under way to determine the optimum dosage, temperature, and period of exposure to insure the destruction of the insect. Attention is also being given to the penetration of the gas in soils of different types and with varying degrees of moisture, and the effect of the treatment on the azaleas at different seasons of the year.

Extensive experiments have been carried on with stomach poisons for destroying the larvae of the beetle in the soil. The insecticidal action of a stomach poison in the soil is the complex resultant which depends upon the interaction of the soil and the chemical and the degree of activity of the insect. Considerable information has been obtained on the use of lead arsenate and other stomach poisons in the soil, but the knowledge of the action of these materials on the soil, on the plants, and on the insects themselves is far from complete.

Lead arsenate is now recommended to control the larvae of the beetle in lawns and golf greens, but experiments are under way with 560 plots of grass which have been treated with different doses of lead arsenate and different fertilizers, and planted with seven different commercial grasses, in order to obtain further information on the effects of the different treatments on the turf, and the effectiveness of the different treatments in protecting the turf from grub injury.

Extensive experimental work is being conducted with the arsenates, borates, and fluosilicates in the soil in the greenhouse and in 1,050 specially constructed cages in the field, to determine the relative effectiveness of the different materials in destroying the larvae of the beetle in different soils, the period of time that soils treated with

the different materials will remain toxic to the larvae, and the effect of the different treatments on plants growing in the soil.

On the basis of the experimental results obtained thus far, lead arsenate has been recommended and has been used successfully on the whole in the treatment of over 1,200,000 square feet of soil about the roots of 316,000 evergreen and deciduous plants in commercial nurseries to destroy the larvae of the beetle. A group of evergreen and deciduous plants representative of the types handled by the commercial nurseries is now being grown in the laboratory nursery in soil poisoned with lead arsenate.

It was early realized that in order to continue the use of lead arsenate as a treatment for the soil about the roots of growing nursery stock it was necessary to develop a method of determining by chemical analysis the thoroughness of the application and the concentration of the poison in the soil. A method for analyzing the soil has been developed, so it is possible to maintain the proper insecticidal concentration of the poison in the soil and to avoid causing excess injury to the plants. During the spring of 1930 over a thousand samples of poisoned soils were taken from the experimental nurseries or from commercial nurseries and examined by this procedure.

BEETLE-INSECTICIDE INVESTIGATIONS

As a result of studies made with limes and other inorganic white materials as repellents for the beetle, it was found that zinc oxide, basic lead carbonate, zinc sulphide, and titanium dioxide were promising. Among the volatile materials which have shown indications of being repellent to the beetle are pine-tar oil, bone oil, and chloronaphthalene. Effort is now being made to prepare fractions of these oils applicable for beetle control under conditions in which it is impossible to use a poisonous material.

In an experiment with 500 traps carried out during the summer of 1929 on a 15-acre lawn 1,876 pounds of beetles (approximately 10,000,000 individuals) were captured. A survey of the soil of this area showed many millions of larvae which were later poisoned with lead arsenate. A new bait for the traps, in which the geraniol and eugenol content has been increased, has captured over two and one-half times as many beetles as did traps containing bait prepared in accordance with previous recommendations.

THE ESTABLISHED FLY PARASITES

The parasite *Centeter cinerea* Aldrich has now spread over some 90 square miles. In 1929 five additional colonies of this parasite were started in the heavily infested areas surrounding Philadelphia. Single colonies were also placed at Harrisburg, Pa., and Stamford, Conn. Checks on these colonies show that establishment occurred in almost all cases, including Harrisburg. The value of this species as a controlling influence on the Japanese beetle is not certain, as its habits and biological development are not well synchronized with the appearance of its host in this latitude.

Prosena siberita Fab. is established in the Moorestown district, but as yet is too sparsely distributed to effect a notable parasitism of the Japanese beetle larvae. Observations made in 1929, however, indicate considerable increase in numbers as compared with the year previous. This species, which is dependent on late-maturing larvae, has not met optimum conditions in New Jersey, and as a consequence two new colonies were started in areas in Pennsylvania where late-maturing host larvae are more abundant.

Dexia ventralis Aldrich, like the preceding species, has not met favorable conditions in the Philadelphia district. Unfortunately, no increase has been noted in the colony established in New Jersey during 1929. Since late-appearing host larvae are necessary for its success, advantage has been taken of the topography of Pennsylvania and a more favorable habitat has been selected. This latter point has not yet been reexamined since liberations were made there.

THE ESTABLISHED WASPLIKE PARASITES

Tiphia popilliavora Rohwer is well established in a large mother colony about 3½ square miles in area. In August, 1929, 10,100 females were collected from this colony and used to establish 101 other colonies in infested areas in New Jersey and Pennsylvania. Recoveries from former colonies started in similar fashion have been most encouraging, showing that the species is readily established when units of 100 females are placed under favorable conditions. To date this species has been liberated in 145 localities.

Tiphia vernalis Rohwer, which has been recovered from the several points of liberation in previous years, has shown a marked increase in numbers in two localities, namely, Philmont, Pa., and Medford, N. J. The indications given by the 1930 scouting are that the Philmont colony will perhaps be large enough next season to permit of subcolonization from that center. In addition to the colonies of this species from which recoveries have been made, seven new colonies with about 6,000 imported females were started this spring. One such colony is located on Long Island, N. Y., making the total number of localities for the species 19.

THE FOREIGN PARASITE WORK

Parasite material has been received in large lots and in good condition from Japan. Continued introductions are planned for certain species. It is essential, however, that considerable research be conducted to determine a number of points concerning the species which have not yet been successfully introduced, to ascertain, if possible, why failure has occurred. This research should also include studies of certain rare species in order to ascertain if they are more abundant in localities hitherto unexplored. It is felt that one man, free from other responsibilities, should be assigned to this work.

MISCELLANEOUS INSECTICIDES

Investigations of the more fundamental questions relating to insecticides have been continued in the laboratory in Washington and at the field station at Sligo, Md., certain phases of these investigations having been carried on in cooperation with the Bureau of

Chemistry and Soils. In April, 1930, a commodious laboratory building was rented at Takoma Park, Md., which has been equipped for various kinds of work relating to problems of insect toxicology and physiology as well as other special studies. The force in Washington has been moved to this new station, and the personnel at the Sligo laboratory has been transferred to the new quarters.

During 1930 a comparison was made of four methods of determining the relative toxicity of stomach-poison insecticides, the compounds used being acid lead arsenate and sodium fluosilicate. A total of 32 stomach poisons were investigated by the "sandwich method" as to their relative toxicity. Only two of these materials, manganese arsenate and p-nitrosodium-ethylanaline, appear to deserve further study. Some time has been given to developing a sensitive electroscope for the measurement of minute quantities of thorium B. This instrument is now being used for determining the distribution of lead in insects. Studies of the toxicity of rotenone as a contact insecticide are under way. Information has been obtained about its toxicity relative to that of nicotine, the effect of spreaders on its toxicity, the effect of hydrogen-ion concentration on its toxicity, and the change during storage in the toxicity of sprays containing it. Studies in the tropisms and behavior of insects have been continued. A paper has been submitted for publication on the tropisms and sense organs of the Coleoptera, which is a companion paper to the one already issued on tropisms and sense organs of the Lepidoptera. In the search for attractants and repellents, an improved feeding method was devised and used to determine whether bean beetles (the insect used on account of its availability) like or dislike the four classes of substances that produce the four human attributes of taste. It was found that they disliked water containing salts, acids, bitter materials, and saccharine. However, they liked other sweet substances tested, such as cane and grape sugars, and different forms of molasses. Bean foliage sprayed with arsenicals was repellent but not sufficiently so to prevent its being eaten. Lead arsenate was most repellent, magnesium arsenate was less so, and calcium arsenate least repellent.

In connection with the determination of what injury, if any, would result to peach trees from repeated annual use during the dormant season of lubricating-oil emulsions, the eighth annual oil treatment was given to trees during the winter of 1929–30. No injury was apparent to trees after eight years of treatment with 3 per cent oil emulsion, and this test has therefore been concluded. Emulsions of 3, 6, 12, 15, and 25 per cent of oil have been used on peach trees during the dormant season for three years past, and considerable injury from the 15 and 25 per cent emulsions has been noted. A 10 per cent emulsion was again used on a block of trees which received the same treatment last year, with no cumulative effect. A test of paradichlorobenzene in 1 and 1½ per cent lubricating-oil emulsions as a treatment for the San José scale gave no better results than the use of emulsions alone.

Further experiments in the development of a cold-stirred lubricating-oil emulsion, in which potash rosin fish-oil soap was used as an emulsifier, confirmed previous experience with this spray for dormant and delayed dormant use, especially for the San José scale and

spider mites. The advantages of this type of emulsion are that it will mix readily with most hard waters. It has a higher oil content and lower freezing point and requires less costly equipment in its preparation. Instructions for making the emulsion were given in a special mimeographed circular (E–277).

Dormant-spray experiments with lubricating-oil emulsions at Yakima, Wash., during 1929–30 have shown that winter-strength oils applied before the middle of March do not appreciably affect the set of fruit, but that when applied later than this the set of fruit is smaller than on trees sprayed with lime-sulphur wash or on trees not sprayed at all. The results indicate that an oil with a sulphonation test of 65 is safer than one with a sulphonation test of 50; in other words, the more highly refined oil is the safer.

PLANT DISINFECTION

In connection with studies of the action of the high-frequency electrostatic field on insects, it was found that a field having a frequency of 25 meters and a flow of 4 to 6 amperes killed insects only on long exposure, but it killed or seriously injured growing plants within a few minutes. The electrostatic field apparently affects the organism by heating the tissues to a high temperature. Experiments with hot water as a treatment for fruit stock infested with the oyster-shell scale or with the San José scale indicate that the former species can be destroyed by immersion in water at 112° F. for 30 minutes or in water at 120° for 20 minutes. The San José scale was not killed by the treatment at 112° but was destroyed at 120°. Apple, peach, and pear stocks were immersed successfully while dormant for periods of time sufficient to kill insects, but plum, quince, and cherry stocks were severely damaged by the treatment.

A method of treating baskets of fresh blackberries, raspberries, strawberries, gooseberries, currants, blueberries, and peaches to destroy the Japanese beetle and certain other insects has been developed, and was used successfully in the treatment of several thousand baskets of fresh fruit during the season of 1929. The fruit was subjected to a fumigation with carbon disulphide in the proportion of 10 pounds to 1,000 cubic feet for a period of two hours, at a temperature of 80° F. This treatment was fatal to the insects exposed, without appreciable detrimental effect on the appearance, edibility, or keeping qualities of the different fruits.

NUT INSECTS

The bureau has been represented on the department pecan committee which was organized by the Director of Scientific Research for the purpose of coordinating all of the department's investigations dealing with the pecan industry. Partly as a result of the activities of this committee the chamber of commerce at Albany, Ga., has provided the Department of Agriculture with a large laboratory building for the use of the various department investigators who are working on the pecan in that district. This building, which was practically ready for occupancy on June 30, will provide working space for representatives of the Bureaus of Plant Industry and Chemistry and Soils, as well as for the Bureau of Entomology. A much better coordination of the work of the various agencies is certain to result.

PECAN NUT CASE-BEARER

The damage caused by the pecan nut case-bearer is particularly conspicuous during years when the nut crop is unusually short, and this has been the case during the crop season of 1930. In the eastern part of the country, however, this insect is not regularly seriously injurious. For several years records have been made of the extent of nut case-bearer infestation during the course of record taking of experimental spraying operations. Thus in one grove, in 1926, of 174,255 nuts examined, 1.4 per cent were infested. In another grove during the same year it was found that of 42,633 nuts examined, 2.17 per cent showed injury. Of 58,396 nuts examined in 1927, 0.5 per cent were infested, and in 1929, 3.44 per cent of infested nuts were found in 137,871 examined. During the years 1926 to 1929 the infestation for southern Georgia as a whole averaged well under 10 per cent.

Extended information on the biology of the nut case-bearer has now been obtained, though there are numerous points still requiring study. Much experimentation has been done in groves in spraying and dusting with arsenicals and other insecticides. The tenderness of the foliage of the pecan to arsenicals greatly limits the dosage and number of sprayings that may be given, and to date no arsenical has been found which at the same time is noninjurious to foliage and effective on the insect. In the hope that a detailed study under controlled conditions in the laboratory would disclose some point in the behavior and feeding habits of newly hatched larvae of which advantage could be taken in orchards, much time during the fiscal year was given to such investigations. However, no important new leads were found.

At the Brownwood, Tex., station, where the pecan growth is still largely that occurring in river bottoms and is often of considerable size, special attention has been given to the possible utilization of parasites for the nut case-bearer, as well as for other pecan insects. The egg parasite *Trichogramma minutum* Riley is being reared in fairly large numbers and has been found to parasitize freely the eggs of this insect in the field. Investigations are under way with another parasite of this case-bearer and also of the shuck worm, namely, *Perisierola cellularia* var. *punctaticeps* Kieffer, and methods have been devised to propagate it. With the present limited facilities, some 25,000 individuals were bred and liberated during the season 1929. In the southeastern part of the pecan belt, with headquarters at Albany, Ga., parasites of the case-bearer have been under inquiry for some years. In view of the difficulty and expense involved in the use of sprays in pecan orchards, it is felt that every effort should be made to utilize the natural enemies of these pests to the fullest extent possible. Special attention will be devoted to *Trichogramma minutum*, and it is expected that this egg parasite can be produced in large numbers for liberation another season. If it is found that this egg parasite or other parasites can be propagated and liberated in a way to reduce the damage materially, it is expected that the actual work of supplying these beneficial forms to growers will be undertaken by the interested States or by commercial interests.

PECAN SHUCK WORM

Much additional information has been accumulated during the year on the biology and parasites of the pecan shuck worm, which ranks probably second in importance to the nut case-bearer. It likewise has not proved to be controllable to any extent by the usual insecticides sprayed or dusted on trees. It can, however, be very materially reduced in numbers in groves if careful attention is given to collecting and destroying all pecan shucks or hulls which are on the ground or elsewhere after harvest, since it is mostly in these that the insect passes the winter. Several of the parasites attacking the nut case-bearer have been reared from the shuck worm. It is thus possible to utilize certain parasites for the control of both species, and owing to certain differences in the life history of the pests involved the welfare of the parasites will be favored rather than otherwise.

PECAN LEAF CASE-BEARER

During 1929 experiments were conducted in two pecan groves in the vicinity of Albany, Ga., to determine (1) the relative effects of Bordeaux mixture and hydrated lime as correctives of arsenical injury to pecan foliage, and (2) whether an arsenical cheaper than lead arsenate could be used with Bordeaux mixture for the control of this insect.

As to the first point, it was found that acid lead arsenate and hydrated lime and acid lead arsenate, hydrated lime, and fish oil caused considerable burning to foliage and partial defoliation of the trees, the damage being a little more pronounced where fish oil was used. On the plots where a combination of lead arsenate and Bordeaux mixture, of the formula copper sulphate three-fourths of a pound, hydrated lime 1¼ pounds, water 50 gallons, was employed there was slight foliage injury, but when the strength of the Bordeaux mixture was increased to copper sulphate 1½ pounds, hydrated lime 2½ pounds, water 50 gallons no injury resulted. On other plots where Bordeaux mixture of the formula copper sulphate 3 pounds, lime 5 pounds, water 50 gallons was used with calcium arsenate and Paris green no foliage injury or defoliation occurred. Since the calcium arsenate is materially cheaper than Paris green or lead arsenate, it would appear that this arsenical may be used in the foregoing formula of Bordeaux mixture with safety and advantage, since applications of a combined fungicide and insecticide are frequently desirable as a simultaneous treatment for fungous diseases and insects. Furthermore, it was ascertained that calcium arsenate, pound for pound, is rather more effective than lead arsenate and that Paris green was almost equally so. The addition of fish oil to the Bordeaux mixture-calcium arsenate spray did not materially add to its effectiveness.

BLACK PECAN APHID

The black pecan aphid (*Myzocallis fumipennellus* Fitch) is proving to be a serious pecan pest because of the defoliation of the trees, occurring principally during the summer as a result of its feeding. This injury is followed the next season by a light setting of nuts. Thorough tests have been made of the delayed dormant sprays,

which are usually successful in the control of aphids affecting apple and other deciduous fruits, but none of these has given satisfactory control of the black pecan aphid, perhaps because the eggs, which hatch rather late in the spring, are laid in crevices in the rough bark on the larger branches of the tree. The use of nicotine sulphate with the regular Bordeaux sprays was found to give a degree of control, but treatment of large pecan trees with nicotine sulphate is extremely expensive and is not being practiced by growers.

Biological studies of the black pecan aphid have been made at the Albany, Ga., and Experiment, Ga., laboratories, and considerable attention has been devoted to the relationships of the various parasites of this aphid to other hosts which may be present in close proximity to pecan orchards.

OBSCURE SCALE

A major project of the Shreveport, La., laboratory has been the study of the obscure scale (*Chrysomphalus obscurus* Comst.), a species concerning which not very much has been known, and rather comprehensive biological studies have been made. This scale, which attacks the pecan, seems to be a slow-growing insect and develops only a single generation a year. Tests of lime-sulphur and of various oil sprays have demonstrated that it is not satisfactorily controlled by any of the dormant applications which have been found effective against many other diaspine scales. The reason for this has not yet been determined, though it was noted that the wax covering of the insect is comparatively dense.

CHESTNUT WEEVILS

Chestnut weevils have continued to be the major problem at the laboratory at French Creek, W. Va. As indicated in previous reports, these weevils constitute the limiting factor in the development of a blight-resistant variety of chestnut to replace the native nuts. A practical method of controlling these weevils, based upon recent experiences, appears to be in sight. The treatment consists of applying to the trees a heavy whitewash of hydrated lime. This acts as a repellent of the weevils and thus materially reduces the oviposition in the chestnut burrs. At Bell, Md., 300 nuts from whitewashed trees yielded three weevils, whereas a similar number of nuts from untreated trees yielded 145 weevils. At French Creek, W. Va., 75 per cent of the nuts from treated trees were sound as against 33 per cent sound from untreated trees. Favorable results have also been obtained by treatments of the soil with carbon disulphide and with ethylene bromide for the destruction of the grubs therein.

PEACH INSECTS

PLUM CURCULIO

An unusually serious situation developed in regard to certain peach insects during the season of 1929. The plum curculio, always present in orchards, was extremely abundant and destructive, and the spread and increase of the recently introduced oriental fruit moth added very materially to the damage, especially in certain

districts. In planning the work on peach insects, beginning with the spring of 1930, it was determined to recheck the earlier results as to the effectiveness of various treatments for the curculio on peach and to develop, if possible, supplementary control measures. This work was inaugurated at the Fort Valley, Ga., laboratory.

Both in the laboratory and in the field a number of poisons other than lead arsenate have been under test for some seasons. This work was continued during the present fiscal year. The problem is to find a material that is poisonous to the curculio but does not injure the foliage and fruit. The almost invariable injury to peach foliage from lead arsenate, the best poison now available, greatly limits the degree of curculio control which otherwise could be obtained by spraying. Of the materials under experiment potassium fluosilicate appears to be a very promising substitute. Following laboratory tests and small-orchard experiments, larger-scale work was undertaken in the spring of 1930. Elberta trees were given four applications of potassium fluosilicate, 2 pounds to 50 gallons, without lime, the last two applications being applied in a fungicide on some of the trees. There was no fruit injury whatever and practically no injury to the foliage. From this one year's orchard test potassium fluosilicate, without lime, appears to be a safer insecticide on peach than lead arsenate. The fact that lime contributes to injury from this material, however, complicates the use of sulphur-lime fungicide for peach diseases.

Probably the most important supplementary measure in curculio control is to gather from the ground under the trees the many peaches which fall early in the season because of curculio punctures, and those which are thrown off by the tree as the so-called "June drop." A considerable percentage of these drop fruits contains grubs of the curculio, which when grown will desert the fruit and burrow into the soil to complete their transformation to adult beetles. Gathering drops has been urged by the bureau for a number of years, and the practice is growing in favor among orchardists. The best way to dispose of these drops, which often accumulate in large numbers, to insure destruction of the contained grubs, has been studied during the year. A number of materials have been used in an experimental way in trays and containers to simulate conditions of the soil under the trees. Paradichlorobenzene, emulsified in mineral oil and sprayed on the drops, gave the best results and appears promising for the purpose. Experiments are in progress to determine the effect on the grubs in peaches of exposing the fruit in the middle of tree rows to the intense heat of the sun on the surface of the soil. No insects whatever have emerged to date from the drop peaches thus exposed, whereas emergence of the beetles from similar lots of drops kept in the shade has been about normal. Tests are under way with carbon disulphide, paradichlorobenzene, and other materials for the destruction of grubs and pupae in the soil after they have escaped from the drop peaches under the trees, to supplement the work of gathering drops and thus further reduce the beetle population in orchards. Tests have also been made to determine how deep in the soil it is necessary to bury drop peaches to prevent the escape later of the developed adults. Beetles have been noted to emerge from drops covered with soil to a depth of 18 inches, which is the maximum depth tested.

The infestation of southern peach orchards by the plum curculio during 1929 was the heaviest since 1921, and the loss from the insect amounted to many millions of dollars. To avoid a repetition of this in 1930, a curculio-suppression campaign was inaugurated in January through the delivery of lectures before various southern horticultural societies, through meetings with State extension agencies, the distribution of publications, and otherwise. The growers themselves cooperated heartily in this effort by giving unusual attention to the operations necessary; namely, spraying and dusting at the proper season, the picking up of drop peaches, the use of curculio catchers, etc. The insects did not begin to leave hibernation in the Georgia peach belt until about the middle of March. This date was so late that it was believed that injury from second-generation curculios would be unimportant, and subsequently this belief proved to be correct. As a result of the campaign, aided greatly by favorable weather, the peach growers of the South marketed a crop of unusually good quality.

ORIENTAL FRUIT MOTH

The oriental fruit moth has now invaded practically all important peach-growing districts east of the Rocky Mountains from Canada to Georgia. Its injury during 1929, especially in the more recently invaded districts, was severe and was the cause of much complaint from growers. For several years the bureau has been continuously engaged in investigations of this insect, principally with headquarters in New Jersey and Georgia and, more recently, in Indiana, in cooperation with the Indiana Agricultural Experiment Station, and much has been learned about its biology and habits. The larva, which is the damaging stage, attacks a wide variety of fruits, and the insect is now recognized as an important apple pest. The habits of the larva on peach are such that it is not amenable to control by the usual spray applications of arsenicals or other stomach poisons. Experiments thus far have not developed a satisfactory method of treatment, despite the extensive work which has been and is being done by State and Federal workers.

One of the hopeful methods of control, as indicated by rather limited experiments, is the employment of so-called bait traps. These involve the exposure in containers in the tree tops of fermenting molasses, fruit juices, and similar materials to attract and trap the moths. The results in southern Indiana during 1929 so impressed a number of fruit growers that funds were made available by Congress in the first deficiency act to inaugurate two large-scale experiments in bait trapping and to enlarge the research work under way. This bait work, begun in the spring of 1930, is located in two important fruit districts, namely, in northern Georgia, with headquarters at Cornelia, and in southern Indiana, with headquarters at Vincennes. In each location approximately 500 acres of orchard are under experiment, and each tree in the orchard is supplied with a bait trap, there being about 50,000 traps for each area. The severity of the winter of 1929–30 greatly injured peach trees in the Vincennes district, so conditions for the experiment at that place were far from ideal. Some data, however, can be secured with reference to the peach, and, more especially, the apple, which in this district is an important crop. Conditions for the work are much more favorable

in the northern Georgia district, but the insect has not been so abundant during 1930 as it was during the preceding year. These large-scale experiments, eliminating the effect of migration of the insect, should show, when the results for the season are tabulated, what may be expected when bait work is carried out by orchardists in a thoroughgoing and cooperative manner. Many interesting facts are being determined concerning the reaction of the insect to different baits, its movement in orchards, etc.

In view of the ineffectiveness against the fruit moth thus far of the usual methods of control, special attention is being given to the possible utilization of its natural enemies. Since the insect made its way to North America, about 1910 or 1911, it has been attacked by a surprisingly large number of native parasites, a few of which are proving important. Careful studies of the biology of two parasitic insects have been made and are in course of publication. An increase in funds in the first deficiency act permitted material enlargement of this work. Arrangements have been made for the propagation and liberation in large numbers of two or three of the more promising parasites. During 1929 fair success was obtained in breeding in quantity *Macrocentrus ancylivora* Rohwer, by far the most important indigenous species to date. In addition to the fruit moth, this parasite attacks the strawberry leaf roller (*Ancylis comptana* Froel.). As a host, the latter is more easily handled in the laboratory than is the former, but there are only three broods yearly, and it is more susceptible to disease in confinement. Peach twigs, up to the time they begin to harden, provide the best medium for the fruit moth larva, after which cut apples can be utilized with fair success. With this parasite it was possible to obtain from 70 to 80 per cent parasitism of host larvae, but about 50 per cent was all that could be reared to the cocoon stage. It appears that successful mass production of *M. ancylivora* will be possible if the question of host larvae can be satisfactorily met. In the spring of 1930 some 55,000 peach twigs infested by first-brood fruit moth larvae and 210,000 first-brood strawberry leaf rollers were collected. These collections have been supplemented by the exposure of several thousand larvae to the parasite in captivity. (*M. ancylivora* was emerging by July 1, 1930, at the rate of about 1,500 per day, a total of 28,000 having emerged.) Thus far 68 colonies have already been distributed in Connecticut, Pennsylvania, Ohio, Indiana, Illinois, Kentucky, North Carolina, South Carolina, and Georgia. A total for the season of about 35,000 individuals of this species is expected. Several of the States, as well as Canada, have been collecting parasites in New Jersey, and in this work the Bureau of Entomology and the New Jersey Agricultural Experiment Station have cooperated. A total of 109,000 infested peach twigs and 270,000 strawberry leaf rollers have thus been obtained for use in the States mentioned.

Other parasites than *M. ancylivora* are receiving attention. *M. delicatus* Cress., it has been found, can be propagated about as easily as its cogener. *Ascogaster carpocapsae* Vier. and *Phanerotoma tibialis* Hald. can also be produced in large numbers. *Glypta rufiscutellaris* Cress. develops readily on fruit-moth larvae, fed on thin slices of apple. The effort to produce *Trichogramma minutum* for preliminary studies in connection with mass liberation indicates a need for special equipment, especially to effect the control of a mite

which becomes abundant in the corn used for developing the host moth as a source of eggs for the parasite. The experience gained will doubtless indicate methods of breeding the parasite for experimental midsummer liberation, especially designed to control the fruit moth on mid-season and later peaches.

Ecological studies of the oriental fruit moth were made during the spring of 1930 and include a regional survey as to parasites attacking the pest, the determination of the rôle of the strawberry leaf roller as a host outside of New Jersey, dissemination studies, and a study of alternate host relationships and of the relation of the insect to hosts other than peach. This work, it is believed, will develop important information, but sufficient results have not thus far been secured to warrant particular mention.

The activities of the fruit moth in the middle Georgia peach belt are less at present than at any time since its establishment in that district. During the course of orchard experiments for the curculio and the fruit moth many thousands of peaches have been examined in which infestation did not average in excess of 1 per cent. These data serve to confirm earlier observations indicating that the insect will not be a factor of importance in the middle Georgia peach belt because of the time of harvest of the principal varieties of peaches grown.

LESSER PEACH BORER

Further tests of the paradichlorobenzene-cottonseed oil wash as a paint for areas on the trunks of peach trees infested with the lesser peach borer confirm earlier results as to the effectiveness of this combination. A practical treatment for this borer, frequently important in southern orchards, has thus been found and its value demonstrated. It can doubtless be used on a considerable number of insects infesting the bark of various shade and other trees. A public-service patent covering this discovery has been applied for.

GRAPE BERRY MOTH

Work with grape insects has been mostly limited to field experiments in the control of the grape-berry moth in cooperation, as formerly, with the Ohio Agricultural Experiment Station, with headquarters at Sandusky, Ohio. Because of the severity of infestation by this insect in vineyards in the northern Ohio grape belt and the corresponding necessity for thorough and late spraying, the arsenical residues on harvested fruit, resulting from the spray schedules employed, have been seriously objectionable. Continued effort has, therefore, been made during the year to determine what changes in the schedule and spraying materials would meet the situation. It now seems clear from extensive tests that the grape-berry moth can not be controlled on grapes with lead arsenate without leaving an excess of poison on the ripe fruit. This is due to the necessity of applications in late July and August for the second and very damaging brood. Other spray materials for late treatments must, therefore, be found, and use made of all possible supplemental measures of control. A large number of arsenicals have been tested as substitutes for lead arsenate, but all of these when employed at sufficient strength and with sufficient frequency to effect control have left objectionable quantities of poison on the ripe grapes. Tests of

numerous other materials, especially for the late application for the second brood, have involved several plant extracts, as commercial Derris extract, 1 to 800, commercial Pyrethrum extract, 1 to 400, and nicotine sulphate, 1 to 800, with 1 per cent commercial white-oil emulsion. Results have varied greatly, some of the materials showing a distinct gain in percentage of sound fruit as compared with plats in which a late spray of lead arsenate was omitted. In none of these materials, however, has there resulted uniformly a control comparable to that obtained from lead arsenate. Special tests are under way with rotenone and with several of the fluoaluminates, as well as other compounds of fluorine, in cooperation with the Bureau of Chemistry and Soils. Some of these fluorine compounds are apparently not seriously injurious to grape foliage, and it is hoped that they may have worth-while insecticidal qualities.

Various adhesives and spreaders for sprays have given good results. Thus fish oil combined with a readily available commercial product gives a much more even coating of the spray material over grape berries than can be obtained with either resin fish-oil soap or fish oil alone. Furthermore, the clotting of spray materials resulting from the spray mentioned is found to be greatly decreased and there is a better penetration of the grape cluster by the spray. A manuscript giving detailed results of tests over the past several seasons is in the course of preparation.

In connection with experiments during the past two seasons to determine possible changes in the time to make spray applications it was found that a preblossom spray did not materially increase control of the first brood of berry worms. If the spray is applied directly after the blossom period, however, and repeated about one week later results are decidedly better than those obtained by applying the first spray about five days after blossom and the second some three weeks later, as is the present rather general practice.

CULTURAL METHODS OF CONTROL

Special attention is being given in vineyards to cultural methods of reducing berry-moth abundance and avoiding the necessity of late spray applications. During the year it was found that in the heavier soils a large proportion of the adults of the grape berry moth were unable to emerge successfully from a covering secured by the usual plowing or disking toward or away from the vines. The plan of work under way to further test the value of disking and concentrated first-brood spraying on a large scale in vineyards is indicated below:

(1) Concentration of spraying against the first brood of berry worms. This includes two spray applications within a 10-day period after the falling of bloom. Later sprays with materials likely to leave excessive arsenic residue to be omitted. Sprays against the second brood limited to nonarsenical materials.

(2) Plowing or disking toward the vines during midsummer, leaving the ground under the trellis in condition for the winter. This cultivation to be given before heaviest emergence of moths from the first brood has taken place, to bury any of the pupae in cocoons

which may have fallen from the grape leaves before emergence, and before cocoons of the overwintering brood are formed, so that these may be exposed on the surface of the ground during the winter.

(3) The ground so treated to be left undisturbed until the following spring in order to avoid giving protection to the overwintering cocoons from the second brood which are on the surface of the ground under the trellis.

(4) Finally, the ground to be thrown away from the vines in the spring, as is the usual practice; this to be finished before the blooming period of grapes, which is the period of heaviest emergence of the moths from the overwintering brood. This covers cocoons which have been present on the surface during the winter, and prevents to a large extent the emergence of moths in early summer.

CODLING MOTH

INSECTICIDES

Because of the spray-residue situation as a result of spraying apples for the codling moth, it has been necessary to continue experiments in the laboratory and field with possible substitutes for arsenical sprays. With the progressive reduction of the quantity of arsenic permitted on harvested fruit entering interstate commerce, the problem of combating the codling moth with arsenical sprays becomes more and more acute and brings in apple-growing regions which otherwise would scarcely be involved. Fortunately, the washing of fruit with dilute hydrochloric acid, with subsequent rinsing with water, has been developed to a very practical degree, and is already in large use in the arid apple-growing districts and will doubtless be followed in numerous apple districts of the East wherever late broods of the codling moth are troublesome. There is none the less urgent need of insecticides which are unobjectionable from the residue standpoint, not only for fruits but for many other plants used in the fresh state as food.

As indicated in previous reports, several fluorine compounds have been under test. While the materials of this group have proved inadequate in the humid portions of the country, several have been found to be nearly equivalent in effectiveness to lead arsenate in the arid sections of the Northwest. The most promising of these at present appear to be cryolite (a double fluoride of sodium and aluminum) and the fluosilicates of potassium and barium. Two applications early in the season of lead arsenate, followed by applications of cryolite, according to the regularly recommended spray schedule, resulted, in the experiments at Yakima, Wash., in better control of the codling moth than was obtained with lead arsenate, and very little arsenical residue was found on the fruit at harvest time. No foliage injury resulted in the Northwest from the use of any of the fluorine compounds under test. Cuprous cyanide has given fairly satisfactory control of the codling moth, although the results have been poorer than those obtained with the fluorine compounds. Tests

18061—30——3

are being made at Bentonville, Ark., of manganese arsenate, which has been reported to be a fairly satisfactory substitute for lead arsenate, its chief advantage being in the elimination of lead, which is considered equally or even more objectionable than the arsenic.

The combination of nicotine sulphate with weak white-oil emulsions has continued to give very encouraging results in the tests conducted in the Northwest and at Wichita, Kans. In the Northwest, where practically no rain falls during the growing season, this combination has proved equal in effectiveness to lead arsenate, compared application for application. In Kansas, during an unusually dry season, this combination was nearly as satisfactory as lead arsenate. There is still some doubt as to how practical such combinations will be in portions of the country in which heavy rains frequently occur during the growing season. The combination oil-nicotine spray is more expensive than lead arsenate, but in addition to controlling the codling moth it reduces the percentage of sting injuries much more than does lead arsenate, and also has an important value in the control of various soft-bodied insects, such as leaf hoppers and spider mites.

Tests on a field scale of combinations of white-oil emulsion at low strength with Pyrethrum extract and with Derris extract, as well as tests of nicotine tannate, are being conducted at Yakima, Wash., Bentonville, Ark., and Wichita, Kans., and laboratory studies of the same and other materials are under way at Vincennes, Ind. Rotenone, one of the more active ingredients of Derris, is being tested in the laboratory and on a limited scale in the field. Some difficulties have been experienced in devising means of diluting rotenone for application, but it is hoped that these will be overcome. All of these combinations, if found effective, will have their chief use for the second and later broods of the codling moth, since the early applications of lead arsenate against the first brood in most parts of the country do not result in excessive residue at harvest time. In the Northwest, however, the lead-arsenate schedule can not be continued after the first cover spray against the first brood without causing excessive residue.

Studies are under way of various penetrating oils that may possibly be used against the hibernating larvae in order to reduce the population which carries over winter on the trees to start the infestation another season.

Chemically treated bands have continued to give good results. For instance, in one test conducted in the Northwest, nine bands treated with beta-naphthol, oil, and aluminum stearate gave a catch of 4,991 larvae and only three individuals succeeded in reaching the adult stage. Aluminum stearate has been found to be of value as a binder and absorbent for the beta-naphthol and oil, increasing somewhat the efficiency of the bands. Tests in which a half of each band was treated and the other half left untreated indicated that the beta-naphthol and oil have no repellent effect upon the worms. Chemically treated bands, when used on apple trees of such age as to develop bark scales, have not caused commercial injury in any of the tests conducted.

BIOLOGY

A survey has been undertaken to determine the present distribution and status of the more important parasites of the codling moth in representative sections of the United States. Headquarters for this work is at the Takoma Park, Md., laboratory. To this laboratory material is sent in by bureau and State collaborators from about 25 localities, and where necessary rearings are made. The most widely distributed and useful of the parasites thus far obtained is *Ascogaster carpocapsae* Vier. It was introduced some years ago from its normal eastern habitat into the Yakima district of Washington, where it is attaining a degree of effectiveness in certain orchards. This species seems to be absent from other western and southwestern fruit districts, and the plan is to establish it in such localities as soon as practicable. At the Bentonville, Ark., laboratory investigations are under way of the predatory beetle *Tenebroides corticalis* Melsh., which in that district has been observed to be an important enemy of the codling moth.

The study of variation in the population of the codling moth throughout a representative orchard, which has been undertaken at the Wichita, Kans., laboratory, is being continued. The information obtained from this study should enable one to understand more fully the dispersion habits of the moth and should also be helpful in planning, laying out, and interpreting the results of plot experiments in the field.

At the Bentonville, Ark., laboratory, studies have been undertaken of the various factors influencing egg laying on the part of the moths. Individual pairs of moths are caged on trees in the orchard under practically normal conditions, and the variation in egg laying under different conditions of temperature, humidity, and wind movement are recorded. The information obtained will furnish a better understanding of the factors which influence the normal rise and fall of infestation, egg laying being probably more responsive to weather conditions than any other activity in the biology of the insect.

BLUEBERRY MAGGOT

Investigations relating to the blueberry maggot were continued largely along the lines already in progress at the close of the last fiscal year. The large-scale growers of blueberries in the vicinity of Cherryfield, Me., are now dusting wherever the yield of berries is sufficient to make dusting profitable. Analyses of fruits which have received necessary applications of dust have shown that the danger of objectionable residue of arsenic in the berries at picking time is small, and it now appears that an effective and practical remedy for the blueberry maggot has been developed.

The process of machine washing of berries for the removal of maggots before canning, while desirable in the absence of a better method, is objectionable because it often destroys many uninfested berries by removing the pulp, with a consequent high percentage of skins and also a loss in flavor of the berries. Furthermore, there is a loss in shrinkage, caused by the washing process, which has been conservatively estimated to be 15 per cent of the berries treated when the

maggot infestation is light and from 20 to 40 per cent of the berries when the infestation is heavy.

Life-history and biological studies of the blueberry maggot were conducted during the season of 1929 more intensively than had been possible previously. The time of appearance and duration of life of the flies, a point of primary importance in effecting their destruction by the use of calcium arsenate, has been given particular attention. During the several years that this emergence has been studied, it has been found that the interval has been short and subject to but little variation from year to year, 95 per cent of the flies coming out during the period from early to late July.

Present recommended dates for dusting in Washington County, Me., are between July 13 and 21, the application to be repeated 7 to 10 days later.

A comparative study of the maggots infesting the apple and those infesting the blueberry is being made. All stages of the blueberry form are smaller than those occurring in the apple, but no structural difference has been noted. It has been difficult to effect the transfer of eggs from the blueberry to the apple, but many successful transfers have been made.

Considerable attention has been given to the parasites of the blueberry maggot, and one species, *Opius melleus* Gahan, appears to be the most important, the percentage of parasitism varying widely. This parasite spends the winter as a full-grown larva within the puparium of the host, the adult parasite emerging in midsummer during late July and August at a time when blueberry maggots are present in large numbers in the berries. It apparently has only one generation a year in the area under consideration.

Dusting experiments in 1929 involved 176 acres divided into nine plots. About 6½ pounds per acre of undiluted calcium arsenate was used per application. The results, while not so marked as in former years, owing to the smaller number of the insects, confirmed earlier results as to the effectiveness of the dust when applied in a timely and thorough manner.

CEREAL AND FORAGE INSECTS

The work on insects affecting cereal and forage crops has been, as formerly, under the direction of W. H. Larrimer.

The most important project of this division continues to be research on the European corn borer. The other main projects are ones on which investigations have been planned covering a period of years. Among such projects are those relating to the Hessian fly, the corn earworm, the chinch bug, grasshoppers, the alfalfa weevil, and other primary pests of forage and grain crops. These investigations have been thoroughly discussed in previous reports. The newer projects of the division, or the newer phases of the older projects, are those relating to the occurrence of the alfalfa weevil in southern Oregon, the diseaselike injury of alfalfa and other forage legumes caused by leaf hoppers, the range caterpillar in northeastern New Mexico and the panhandle of Texas, and the control of the Mormon cricket in northwestern Colorado.

EUROPEAN CORN BORER

The enforcement of the quarantine against the European corn borer, as pointed out in last year's report, has been conducted since July 1, 1928, by the Plant Quarantine and Control Administration of this department. The closest possible cooperation has been maintained between the research work of the bureau and the quarantine and control activities of the Plant Quarantine and Control Administration.

The known spread of the corn borer for the season of 1929 may be considered as normal; that is, 20 to 30 miles from the known infestation. The spread in general had a southward trend for the season. The borer has been found farthest west in Boone Township, Porter County, Ind., about 30 miles from the Illinois line, and farthest south in Ohio Township, on the Ohio River, in Gallia County, Ohio. During the season of 1929 the infestation increased in those districts in northwestern Ohio which are considered particularly favorable for the development of the borer. In other districts, such as central Michigan, which are not quite so favorable for the development of the borer, there was an actual decrease of infestation. This illustrates the difficulty at this time of definitely predicting what may happen in any particular area as a result of the inevitable spread of the corn borer throughout the Corn Belt. Commercial damage to corn crops from this insect still remains small or almost negligible and is confined to the older infested area near Lake Erie and to certain particularly favorable areas in southern Massachusetts and Rhode Island. At the time of the preparation of this report—July, 1930—the moths are just concluding their annual flight and scouting for new infestation is just beginning. It will be especially interesting to determine what effect the hot and dry season, unprecedented to date, may have on spread and infestation for the present season.

The work of parasite introduction has progressed more satisfactorily during the present year than in any previous year since the work started, both as to the total number of parasites released and as to efficiency in handling available material. Up to July, 1930, there have been released during the present season approximately 600,000 parasites of 17 species. The recovery of parasites from previous liberations has been very encouraging. In some cases colonies have become sufficiently strong so that collections could be made and material shipped to the more recently infested areas, thus resulting in very appreciable saving in the cost of collection and shipment and an increase in the efficiency of distribution of parasite material, to say nothing of reduction in mortality of parasites and the elimination of all risk of introducing secondary parasites.

There has been a long-continued demand, particularly from districts where canning of sweet corn is an important industry and where sweet corn is grown for table use, for a control measure by which an individual farmer may protect his crop regardless of the cooperation he may or may not obtain from his neighbors. This has resulted in a slight expansion of the insecticide work, and by the continuation of the present program of this phase of the work the possibilities of such control will be thoroughly investigated.

Through cooperation with the Division of Agricultural Engineering of the Bureau of Public Roads there now is available special machinery for the control of the corn borer under corn belt conditions. This machinery consists of special plows, stalk cutters, rakes, and low-cutting corn binders. There is in process of development by several of the large manufacturers of agricultural machinery a corn combine intended especially for use in the control of the corn borer. With it corn is cut low, the ears are husked and elevated into the accompanying wagon or truck, and the fodder is then shredded or cut so as to destroy the corn borer and later elevated into a truck for use as silage or scattered on the ground to improve the soil. Progress in this respect has been considered promising to the extent of being almost satisfactory.

This bureau is responsible for an annual conference on the European corn borer, at which there is outlined and projected the definite participation of the various interested organizations of the Dominion and Provinces of Canada, the various bureaus of the United States Department of Agriculture, and some 25 or 30 States immediately concerned in the control of the corn borer. This project represents an outstanding case of cooperation between the bureaus of the department and the various agencies concerned in research and control of the corn borer in the United States and Canada.

ALFALFA WEEVIL

The alfalfa weevil, which originally was known to occur in a comparatively small area around Salt Lake City, Utah, has now spread by its natural ability to neighboring States where conditions affecting the control of this pest are essentially different. Control measures which consist of dusting or spraying with lead arsenate have been developed and have proved very practical for northern Utah and Nevada, but are not meeting with success in the outlying districts. During the summer of 1929 a rather severe infestation was discovered at Medford, Oreg., some 200 miles from the nearest known infestation. Incidentally this is the first known spread west of the Cascade Mountains, and in this new environment the weevil has developed habits quite different from those noted in the older infested area. In order to develop control measures a complete study of the insect has already been begun under the conditions of this new infestation.

The investigation of the manufacture and movement through commerce of alfalfa meal as a possible means of distributing the weevil has been continued. Further information has been obtained bearing out previous results indicating that when alfalfa meal is manufactured under proper precautions the danger of distributing the pest through commerce in the meal is very slight, if not negligible.

Further evidence has been obtained indicating the danger of transportation of the alfalfa weevil in freight cars used in the shipment of alfalfa hay within the infested districts.

LEAF HOPPERS AND ALFALFA

There has recently been recognized a malady known as "alfalfa yellows," "clover spot," etc., which is a new trouble for this valu-

able group of forage crops and soil builders. The injury is widespread and has been reported from Kansas eastward through Illinois and Wisconsin as far as Virginia. The investigation of the insects believed to be responsible for the transmission of alfalfa yellows and other injuries of a diseaselike nature has developed a number of secondary problems not apparent when this work was first undertaken. Preliminary studies have indicated most certainly that leaf hoppers are involved in the trouble and may be entirely responsible, and the possible occurrence of several species where one was previously considered has affected materially the plans to develop control measures for these insects. Because of a definite allotment of funds to this project these investigations can now be undertaken on a much more satisfactory basis.

RANGE CATERPILLAR

The outbreak of the range caterpillar has continued, and this insect is now doing serious damage to the valuable blue grama grass on the finest cattle ranches in northern New Mexico and the panhandle of Texas. This caterpillar, which is about 3 inches long, bears on its body many barbed spines which are extremely irritating and poisonous, both to range animals and to man. In addition to the actual grass consumed by the caterpillars there is a further loss of forage, as cattle will not eat where this caterpillar has crawled or fed, because of the webs which it spins and in which are incorporated its poisonous shed skins and spines. Owing to the very low value of the range grass per acre none of the usual methods of control are practicable. In an outbreak some 15 years ago control was brought about by the natural increase of an egg parasite of this pest. An effort is being made to speed up the increase of this parasite so that control which under natural conditions may be expected in from 6 to 8 years may be brought about in 3 or 4. Although the parasite was very scarce in the spring of 1930, it is now being bred and released in large numbers.

MORMON CRICKET

The serious outbreak of the Mormon cricket in northwestern Colorado has now been brought under practical control by the application of measures worked out by this bureau. Through cooperation with the State of Colorado control campaigns during the past two seasons have resulted in a very material reduction in the number of crickets, and there remain to be cleaned up only the outlying districts away from the cultivated areas. This final clean-up work is extremely difficult because of the nature of the country, but is necessary in order to safeguard against building up a new infestation from these outlying areas. It is hoped that one more season's work will end the present outbreak of this destructive insect.

TRUCK-CROP INSECTS

Investigations of vegetable and truck-crop insects have been continued during the fiscal year under the direction of J. E. Graf and W. H. White.

MEXICAN BEAN BEETLE

The Mexican bean beetle increased its range slightly in the Northeastern States, being found for the first time in Massachusetts and Connecticut. Injury during the latter part of the calendar year 1929 was rather heavy over the major part of the infested area. Owing to the lack of normal precipitation and the warm weather during the early part of the season of 1930, mortality of the beetle was higher than usual, and except in restricted localities injury by the pest was considerably below that of the preceding year. Apparently temperature and sunlight are more important controlling factors than is humidity, since laboratory experiments showed that extremes of dryness or saturation of the air did not have any marked effect on the development of the beetle except where these were accompanied by high temperatures. The effect of the lack of moisture under field conditions is to expose the immature stages of the beetle to the direct sunlight, as the undersides of the leaves are exposed during the heat of the day. Survival of the insect during hibernation did not differ materially from that in the preceding winter, being slightly higher in Ohio and slightly lower in the District of Columbia area and in that of Norfolk, Va.

The results of further experiments with control measures agreed closely with those obtained in preceding years. Magnesium arsenate did not injure bean foliage to any appreciable extent in any of the sections where tested, whereas the use of calcium arsenate resulted in injury in many instances. Lead arsenate caused heavy plant injury. The addition of Bordeaux mixture to calcium arsenate reduced plant injury in all cases and entirely eliminated it in several tests. The addition of Bordeaux mixture to lead arsenate, however, did not produce a safe insecticide. Plant injury by calcium arsenate varied considerably with the brands used. Pyrethrum extracts continued to give good control where used in proper dosages and particularly in cases of comparatively light infestations. Tests with cultural-control methods, including the plowing under of bean fields following harvest, showed that covering adults and larvae with 1 inch of soil resulted in killing most of the insects. Neither adult beetles nor larvae were able to reach the surface when covered with 2 or more inches of loose, fine clay or loam. More beetles reached the surface in fields harrowed or raked after being plowed than in those merely plowed.

Study of a parasite of the bean beetle in the vicinity of Mexico City was undertaken during the year. Infestations of the bean beetle in Mexico are of a spotted character and for this reason the collection of parasites proceeded rather slowly. Investigation of the biology of the parasite was undertaken in the hope that it would be possible to discover the reason for the failure of earlier parasite introductions into this country. During the year more than 2,000 parasites were sent to the laboratory at Columbus, Ohio, but attempts to carry these insects in storage over winter under various conditions met with failure.

BEAN LEAF HOPPER

Further tests on the control of the bean leaf hopper by Bordeaux mixture indicated that copper is a specific poison for this insect, that the copper from Bordeaux mixture sprayed on either beans or pota-

toes is taken up by the plant, and that the insect receives a toxic dose from the copper in the plant juices. These investigations strongly indicated that the sugars in the plant accounted for the absorption of the copper from the Bordeaux mixture. Tests in feeding leaf hoppers on copper solutions of known strength by the use of capping membranes showed that copper in weak dilutions (1:6,500) gave a rather high degree of toxicity.

SWEETPOTATO WEEVIL

Field and laboratory investigations for the control and eradication of the sweetpotato weevil in southern Mississippi and Alabama were continued. This work followed rather closely the plan pursued during previous years and included inspection of stored potatoes and seed potatoes on all farms, and supervision of planting, harvesting, and storing of the sweetpotatoes by the growers. This work was continued in close cooperation with the Mississippi State Plant Board, the Alabama State Department of Agriculture, and the individual farmers concerned. Further progress was made in reducing the number of infested farms. Since January 1, 1930, infestations have been found on only three farms in Hancock County, Miss., and nine farms in Mobile County, Ala. In addition to eradication on numerous individual farms, injury by the weevil has been almost eliminated on all farms, the insect having been reduced to such small numbers that even where it occurs it is found with difficulty.

WIREWORMS

Biological studies of the tobacco wireworm at Chadbourn, N. C., have shown that some of the individuals completed their life cycle in one year, and some in two years, while several are now in their third year in the larval stage. In these experiments the length of the larval stage has ranged from a minimum of 375 days to a maximum (still uncompleted) of 1,064 days. Injury to tobacco in the field was very light, possibly influenced to some extent by the dry spring. Attempts to determine the factors which attract the female beetles to certain fields for egg-laying were a failure, owing to the small number of adult beetles collected. Practically all the insects taken on the screens treated with a tree-banding material were from 3 to 6 feet above the ground.

Experiments on the control of the sandy-land wireworm as a pest of corn gave inconclusive results. In heavily infested fields both treated and untreated plots were completely destroyed. No benefit could be detected from the use of rye as a trap crop.

At Walla Walla, Wash., further field and laboratory experiments were conducted on *Pheletes canus* Lec. and *P. californicus* Mann., the two most destructive wireworms occurring in the Northwest. The laboratory studies were concerned principally with investigation of the activity of the wireworms in the soil, the factors affecting their movement through the soil, and their food habits. A special investigation under laboratory conditions was made on the diffusion of various insecticides in the soil, together with their absorption. Field studies were concerned with the development of an accurate method of measuring wireworm populations in the field and experiments with various insecticides. A further improvement

has been made in the mechanical soil sifter. This is used not only to collect insects for laboratory experiments but also to obtain records of the densities of wireworm populations in order that the effectiveness of various control measures may be measured. While the equipment itself is efficient, it has not been possible as yet to determine the proper size of the area to be screened in order to obtain a count representative of the wireworm population of an entire field or portion of a field. Studies on the temperature requirements of the wireworms showed that the optimum for their activity was between 70° and 73° F. and that the limits of their activity was 59° and 100°. Immature stages of the wireworm desiccate readily where the soil is deficient in moisture. Wireworms showed an ability to recover after long periods of submergence in water. Young larvae a month old were able to recover after submergence for one month. A small portion of the older larvae, including those 1, 2, and 3 years of age, recovered after submergence for six days. Tests of the food habits of the wireworms gave no conclusive results, since they were able to feed and develop on the subterranean portions of a wide variety of plants. Tests of the value of rotation in wireworm control indicate that cropping with alfalfa has some effect in reducing the infestations of wireworms in certain fields and that these beneficial effects begin after the first year. Tests with pyrethrum extracts for the control of wireworms were inconclusive, and no kill in excess of 50 per cent was obtained in any case. In both Washington and Idaho surveys were made to determine the relative abundance of wireworms under various cropping systems followed by individual farmers in the hope that it will be possible to determine a sequence of cropping which will be useful in reducing the heavier losses now suffered.

At Alhambra, Calif., experiments were conducted to determine the optimum temperature for the wireworms and the depths at which they were to be found in the soil at different times of the year. Thirty-five per cent of the larvae were found at a depth of from 1 to 8 inches, a lesser number were found at 13 inches and below, while a few were taken 22 inches below the surface. In temperature experiments the wireworms were active between 50° and 97° F., while 70° appeared to be the optimum. Wireworms which were hatched in acid soils ranging from pH 1.44 to 7.28 are continuing development in these soils. Little or no effect from the differing hydrogen-ion concentration is shown, except that larvae in acid soils appear to be less active than those in alkaline soils. Work has been continued on the development of a wireworm trap in order to develop equipment for testing the attractive values of various baits in the soil without the extensive soil-sifting operations now necessary. While the smaller wireworms appear to be able to escape from these traps, it is hoped that with a slight change a large proportion of all sizes of wireworms which enter the traps will be retained. Further tests of heavy dressings of sulphur as a protection against wireworm injury have given no significant results, and the wireworm damage to potatoes grown in plots containing varying quantities of sulphur has shown no differences. Tests with various materials as stomach poisons have all resulted in failure.

SEED-CORN MAGGOT AS A POTATO INSECT

Further tests of cultural methods for controlling the seed-corn maggot, as a pest of potato seed pieces during the germination period, on the eastern coastal plain, were continued. Maggots in all stages of development were found to feed and reach maturity in seed pieces in which the cut surface did not cork over readily, as the maggots found suitable food on the decaying cut surface. Newly hatched maggots did not live when given freshly cut, sound seed pieces as their only food, but half-grown or older specimens could live upon freshly cut seed pieces. In cages where the maggots could make a choice they invariably selected the improperly corked decaying seed pieces. Maggots less than half grown, when given only corked seed pieces as food, were unable to develop. Those more than half grown were able to pupate but did not reach normal size. The adult flies became very scarce during the summer, and the peak of abundance is reached in the Carolinas during April. They are most abundant in cultivated fields, especially those that are freshly plowed. The flies have been seen feeding on flowers of almost all plants growing in or near cultivated fields. As in the preceding year, suberized seed—that which was corked over before planting—gave by far the best protection from maggot injury. As suberization of the seed appears to be a method which the growers may use readily, its early adoption generally appears certain.

SPOTTED CUCUMBER BEETLE

In view of the inability to rear the spotted cucumber beetle over summer in Louisiana, the biological work on this insect was continued through field scouting from Louisiana northward in the Mississippi Valley. Previous information had indicated that this insect is only a winter resident of the South, the beetles leaving in the early spring and returning in the fall. While no beetles could be found in Louisiana during the summer, they were found in Arkansas and as far north as Columbia, Mo. As a result of the data collected in Missouri, Iowa, and Ohio, the indications are that the species does not hibernate in large numbers as adults north of the southern portion of Missouri, and that this beetle may ultimately prove to be a year-around inhabitant of only a relatively narrow strip south of the lower part of Missouri.

BERRY INSECTS

STRAWBERRY WEEVIL

A study was made of the wild food plants of the strawberry weevil to determine their effect in concentrating the weevil in the vicinity of strawberry fields for estivation and hibernation. It was found that the new generation of weevils, after feeding on the wild plants late in the season, drop to the débris beneath the plant. Thus these native food plants indicate the location of hibernating quarters. The abundance or scarcity of native food plants in close proximity to weevil-infested fields will determine the concentration of the hibernating weevil within such areas and so serve as an index of the number of weevils that may be expected in the strawberry field the following spring. Repeated examinations of débris taken at differ-

ent distances from infested strawberry fields showed that by far the greater number of weevils were taken in the first 10 feet adjoining the strawberry planting. Sulphur with either calcium arsenate or lead arsenate applied to the plants as a dust continues to give satisfactory control in the North Carolina area. The material was particularly effective during the season of 1930, owing primarily to the scanty foliage, which permitted a more effective covering of the developing buds.

CYCLAMEN MITE

Tests were continued to develop an insecticide which could be used in treating strawberry plants for the control of the cyclamen mite. Sulphur did not kill a sufficient number of mites to indicate that it would be useful as a control measure, and in addition the strawberry plants on all plots where the sulphur was used were winterkilled during the succeeding winter. Strawberry plants were submerged for five minutes in a 2 per cent white-oil mixture at 95° F. without apparent injury, and such treated plants were apparently able to stand transplanting better than those receiving no treatment. Preliminary results indicate that the white-oil treatment gave the best control of the mite so far obtained, but this remedy must be tested further.

STRAWBERRY ROOT APHID

An investigation was undertaken to determine whether the strawberry root aphid was concerned, either directly or indirectly, with an abnormal condition of the strawberry plants which was becoming prevalent in portions of the Carolinas and Louisiana. Surveys were conducted throughout Florida, Louisiana, and the Carolinas, and no evidence was found which would directly connect the aphid with injury to the plants. The control of this insect would probably require a radical departure from present cropping methods, since it would be necessary to take into consideration the attending ants, which not only protect the aphid but carry them from plant to plant.

BEET LEAF HOPPER

Studies of the beet leaf hopper conducted in California, New Mexico, Utah, and Idaho were concerned with the effect of climatic conditions and the occurrence of various wild plants on the development and abundance of the leaf hopper. The principal objectives of this work are the accumulation of data which will make it possible to estimate probable injury from the insect and thus outline areas which as a general rule are favorable for beet culture, and the determination of factors responsible for leaf-hopper outbreaks. There is in addition the possibility that this study will disclose the feasibility of control of the insect by interrupting its host-plant sequence, either by the use of competing insects or by establishing a new plant sequence in the areas involved. As these data are carried over a larger number of years they increase in value. The investigations on host-plant susceptibility to disease are concerned with the susceptibility of cultivated and desert host plants of the leaf hopper, since this susceptibility is an important factor in determining the amount of disease carried by the insects when they invade the

beet fields. The capacity of the insects to transmit disease to the beet plants is determined by the disease-carrying ability of the wild plant from which they have migrated as well as by the survival of the disease within the insect. Data thus far obtained, from both laboratory and field studies, indicate the possibility of a definite correlation between accumulated temperatures and time of migration as well as the length of time required for the production of the brood. Breeding areas in the same section may react somewhat differently to winter conditions, and fall conditions of rainfall apparently play an important part in determining the spring populations of the insect. A more intensive survey of the desert areas indicates the importance as migration centers of certain localities not previously suspected. The fourth prediction of probable leaf-hopper abundance in the Twin Falls district, which was based both on hibernation data and on the type of winter, was issued at the end of February. The winter, although showing some divergence therefrom, was closest to that of 1921–22, which preceded a season when an average beet tonnage of 13.52 was produced per acre. Although at the time of writing tonnages for this season are not yet available, it is certain that damage will be greater than indicated by the February prediction. Heavy leaf-hopper flights occurred during the period from May 24 to June 17, coming from a northwestern direction and from areas not previously linked with serious infestations of the Twin Falls district. Traps placed around the areas growing sugar beets have given accurate information regarding direction and time of flights, and this is correlated with the infestation in the fields and the development of disease. Data relative to the height of the flying season have also been obtained by this method, and there appears to be a correlation between the heaviest flights and high temperatures.

Studies on the value of chemical attractants and repellents for the leaf hopper have given only negative results. To judge from tests with insecticides, the beet leaf hopper apparently is not susceptible to copper, as is the potato leaf hopper. Experiments with oil sprays, particularly those of the light oil-Pyrethrum type, indicate thus far that owing to the inadequate kills this method will not be available as an economic measure. The studies of parasites have shown that during the past year several species occurred 200 miles to the north of the range of the beet leaf hopper, and thus their nonspecificity is indicated. Five species of egg parasites have been reared from leaf-hopper eggs in dry Russian thistle, and this appears to be the principal manner and place of overwintering of the parasites in southern Idaho. Laboratory studies include investigation of the life cycle of the parasites, their egg-laying capacity, host range, etc. Such data are necessary not only in determining the parasite requirements for leaf-hopper control but also in furnishing an explanation for the inefficiency of the parasites present.

TOBACCO INSECTS

TOBACCO HORNWORM

The growing objection to the arsenical residue left upon tobacco has indicated the importance of expediting work on the control of tobacco insects by methods which do not necessitate application of

an arsenical. Amyl salicylate has been known for several years to be attractive to the hornworm moths; but since large screen cages were necessary for trapping the moths drawn to the bait, this method could not be used satisfactorily in field practice. In 1929 an apparatus was developed through which the moths were fed a poison. This poison feeder had to be visited only twice a week, whereas it was necessary to attend the traps every day for satisfactory results. Three white funnels, to simulate the Jimson-weed blooms, the favored feeding flower of the tobacco hawk moth, led into the feeder, in which was contained a sweetened and poisoned liquid. Upon the feeder was placed a vial containing amyl salicylate, which served to attract the moths near enough so that they would react to the painted funnels. Thirty-nine of these feeders were exposed in an area containing 9 square miles at approximately half-mile intervals and in the proportion of one for each 9 acres of tobacco. While the efficiency of this treatment could not be determined with accuracy owing to the size of the treated area, control obtained by this method averaged a little above 50 per cent as determined by comparison with check fields outside the baited area. This was the first field trial of the poisoned-bait method and indicates that better control may be expected with an improved feeder used in greater numbers. While the exact degree of usefulness of the method remains to be proved, it is popular with farmers and would readily be adopted if its usefulness were demonstrated.

TOBACCO STALK BORER

Further studies on the tobacco stalk borer in Arizona have shown an abundance of wild host plants of several genera on which the insect is capable of living. Tobacco, potato, and eggplant are the only cultivated plants naturally attacked by the borer. The different types of cultivated tobacco vary in their resistance to borer attacks. *Nicotiana rustica*, a tobacco of high nicotine content, is much more susceptible than many others, plantings being killed outright by the borer, and thus far it has been impossible to protect the plants from serious commercial injury. There is, however, a promise that control methods can be developed which will be useful on other varieties of tobacco. Arsenical sprays and dusts show a repelling effect on the adult borers both as to feeding and as to egg deposition. As many as three overlapping generations of the stalk borer occur annually and this makes it necessary, to protect plants in seed beds, to dust them heavily with arsenicals as soon as they are set out in the field, and to continue the dusting at regular intervals throughout the season.

ARSENICAL RESIDUE ON TOBACCO

A cooperative study with the Bureau of Chemistry and Soils on the quantity of arsenic remaining on the tobacco plant at harvest, after regular treatments with Paris green and lead arsenate for the control of hornworms, has progressed to the point where some definite results may be expected by the end of the season.

MUSHROOM INSECTS

The investigation of mushroom insects and other pests which attack this crop has continued primarily along the same lines as last

year, with special emphasis upon the value of sanitary measures in checking losses. Preliminary experiments have shown definitely that the proper composting of the manure has an important bearing upon infestation of mushroom houses with mites and flies, in that the compost must reach a high enough temperature when it is going through the heating process in the house either to kill any animal life in it or to drive the pest out of the compost where it can be reached with a sulphur or hydrocyanic-acid-gas fumigation. Artificial circulation of the air within mushroom houses in order that the beds in the lower part of the house may reach practically the same temperature as that in the upper part of the house has been practiced with good results. This artificial circulation has been brought about by the use of the ordinary oscillating house fan. Another factor in equalizing the temperature in the beds during the time that the compost is going through the heating process in the house is the raising of the lower bed of the house to 6 inches or more above the ground. If this is not done the temperature will not rise in this bed to a sufficient height to kill or drive out the pests which may be in the compost, and these lower beds will serve as a source of reinfestation to the rest of the house. The indications are that steam sterilization of the surface of the compost pile can be used to good advantage in checking mite infestations. Screening of doors and ventilators with 30-mesh wire has proved of practical value in reducing the losses from mushroom flies. Another factor in preventing losses from mushroom pests is keeping the temperature of the house below 55° F. during the cropping period. Temperatures higher than this serve to promote the rapid multiplication of both mushroom flies and mites.

Ethylene oxide, combined with carbon dioxide to reduce accidents, shows promise, from preliminary experiments, of being useful as a fumigant in mushroom houses, as this fumigant will penetrate uncased compost and kill mites and the larvae of the mushroom flies contained therein.

A development which has proved to be of considerable value to the growers in the control of mushroom flies consists in the improvement of the physical qualities of pyrethrum powder. This has been accomplished by mixing 60 per cent of the pyrethrum powder with 40 per cent of diatomaceous earth. This diluted powder stays in suspension in the air longer than when undiluted and is consequently more effective.

The mite *Linopodes antennaepes* Banks was discovered for the first time doing commercial damage in two localities, the greatest loss from this pest occurring in Ohio.

PEPPER WEEVIL

Experiments in 1928–29 indicated that while the pepper weevil could be effectively controlled by the use of calcium arsenate, under certain conditions aphids would increase to injurious numbers and cause considerable loss to pepper plantings. In view of this possibility many growers were reluctant to use calcium arsenate, and it became necessary to depend to a larger extent upon the cultural methods which had given promise. Field experiments showed that adult pepper weevils survived the winter only in cages containing nightshade or pepper plants and that where host plants do not

survive in the winter weevil infestations the following year are of little importance. Minimum winter temperatures below 30° F. reduce host-plant survival and consequently weevil population. If the winter temperatures do not drop below this point heavy infestations may be expected especially where there are sufficient wild host plants to carry the weevil over winter. During the winter of 1929–30 a large percentage of the nightshade was cleaned up, and the growers are becoming convinced that destruction of nightshade and pepper plants after harvest is one of the necessary steps in pepper culture. Experimental tests with calcium arsenate applied as a dust during August and September, 1929, gave a considerable increase in the yield of peppers, and in no case did aphid infestation follow treatment. The growers, however, preferred to take a chance on the weevil rather than on the possibility of aphid damage, particularly in view of the fact that the arsenical residue must be removed before the peppers are prepared for market.

PEA APHID

In connection with the pea aphid, studies are being continued to determine the relationship between plant growth and aphid injury in order to find an index which will show when treatment for the aphids is necessary. Determinations of plant samples include length, green weight, dry weight, moisture content, and sap concentration. At the same time measurements are being made of the extent and intensity of infestation, of factors influencing the peak of infestation, and of the effect of heavy infestations on the pea vines. Experiments to determine the factors influencing the hatching of overwintering eggs indicate that the percentage of hatching was highest in eggs entirely exposed or with only a little covering and that heavier coverings of various materials appeared to be unfavorable.

CELERY LEAF TIER

Further studies on the biology of the celery leaf tier failed to show where or in what stage this insect spends the summer. Experiments devised to test the ability of the pupae to withstand moisture show that this stage of the insect can not emerge after being in contact with excessive moisture for more than 48 hours. Since the rainfall in Florida averages over 6 inches per month during the summer, it appears doubtful if the insect lives over the summer as a pupa. As usual the moths appeared in the fall after a marked drop in temperature. This occurred on September 23 following the first heavy rain. Female moths captured at this time laid an average of 37 eggs during the first night and lived only a short time. A careful study was made of birds and other natural enemies of the celery leaf tier. Over 226 bird stomachs were collected and examined and several species showed a preponderance of the celery leaf tier in the diet. The stomach analyses gave conclusive proof of the fact that the common birds, both migratory and native, destroy large numbers of the celery tier, and it is possible that during a season that is normal so far as temperature is concerned they play a large part in preventing outbreaks of the pest. Control experiments with various chemicals did not yield any material more effective than pyrethrum dust.

EUROPEAN EARWIG

In connection with the European earwig, special attention has been given to a determination of the food preferences of the insect through an extensive examination of stomachs from various sources. Study of the food of earwigs shows that the main food is of vegetable origin and that under certain conditions these insects are capable of damaging almost any kind of vegetation. Early in the season spores of fungi and pollen are important elements in the food, dandelions and grass also being included. In addition to vegetable foods, the earwig regularly includes animal matter in its diet. This consists largely of aphids and other small insects. But in spite of this habit, aphids have been found damaging roses and other plants on premises heavily infested with earwigs. Reports on this insect from Europe show that as a rule it is regarded as injuring plants, though a small number of investigators claim that owing to its insect-feeding habits it is somewhat beneficial. Data have been accumulated on the seasonal history of the earwig and on the potentialities of the insect as an agricultural pest in rural districts. A survey was made in Portland, Oreg., of the area in which an earwig parasite imported from Europe had been previously liberated. No trace of the parasite could be found, and it appears improbable that it has been established out of doors in Portland. Control experiments have been concerned principally with the testing of various baits and poisons. The poisons showing special promise were thoroughly tested at several dosages. Two types of bait traps have been developed and tested, and one of them gives promise not only of aiding in the concentration of the earwigs but also of maintaining the bait in satisfactory condition over long periods. A bait of wheat bran, fish oil, and sodium silicofluoride gave the best results, both in the presence and in the absence of green food. The exact degree of effectiveness of any poison bait, however, is difficult to determine, since the insects wander about so freely at night that the checking of results obtained can not be done with any degree of accuracy except where the baiting experiments are carried out over wide areas. Studies are being made at several points in the Northwest in order to determine the relation of climatic factors, such as humidity and rainfall, to the distribution and occurrence of the earwig.

VEGETABLE WEEVIL

In California there was one generation of the vegetable weevil in 1929. The first eggs of the year were laid by oversummering adults late in September, and the first grubs were found in the field in early October. Egg laying continued until January. The adults become inactive in the early summer and remain so until fall. The weevil caused considerable injury to carrots and turnips, but the growers were slow about using control measures, many of them waiting until the major portion of the injury had been done. Work on baits was continued, but the promising preliminary results obtained with certain baits in the previous year could not be duplicated. More weevils were collected under old sacks and boards placed between the rows than in the traps. It seems clearly demonstrated that the fall infestations come into the fields from weedy fence rows, and

an attempt will be made to test clean culture on a large scale. In the Gulf region the vegetable weevil is now known to occur in 117 counties in Mississippi, Louisiana, Alabama, and Florida. The spread to the north has been considerably slower than in preceding years. The weevil appeared to survive the cold weather of last winter successfully. Surveys along the northern line of infestation where air temperatures had dropped to as low as 7° to 10° F. resulted in the finding of all stages; the weevils, however, were protected by several inches of snow.

INSECTICIDES

Physiological investigations have been continued in order to determine the effect of the various poisons on insects, with the hope that such studies will lead to the successful development of a stomach poison for wireworms. The investigations included: (1) A study of the enzymes present in the larval and adult potato beetle and of the effect of arsenicals upon their activity; (2) development of a method for determining microscopically the relative distribution of arsenic in insect tissue; (3) determination of the toxicity of contact insecticides as measured by their effect upon the respiratory metabolism of insects; and (4) toxicity studies of wireworms. The work last mentioned has shown that certain poisons give promise of killing these larvae, but since these are repellent to the insects it is necessary to find a chemical which possesses attractive or neutral qualities and at the same time will kill them.

COTTON INSECTS

Investigations of insects affecting the cotton plant have been continued under the direction of B. R. Coad.

The principal change in cotton-insect investigations during the year has been an expansion in the studies of insect pests other than the boll weevil, thus continuing the trend which started several years ago. Nevertheless, the boll weevil still continues to receive the greatest amount of attention.

BOLL WEEVIL

A 15-year period of study of the hibernation, winter survival, spring emergence, and resultant damage of the boll weevil in the Mississippi Valley has been completed, and the first of a series of manuscripts dealing with the various phases of this subject has been prepared. In addition, analyses of similar studies at points elsewhere in the Cotton Belt have been made for comparison with Mississippi Valley conditions, and this general study of records has made possible some revisions in the plan of operation for both the intensive work at Tallulah, La., and the extensive observations elsewhere. At Tallulah it was found that the average winter survival of the weevil over a long period of years was approximately 1 per cent and that, contrary to previous expectations, the winter mortality is more directly influenced by the number of times the temperature goes below freezing than by the extreme minimum temperature of the year.

Comparisons of different hibernation shelters indicate their relative importance in various seasons. These can be very closely correlated with the distribution of infestations in the fields in the spring, and thus a more intelligent control program can be planned. Some materials of great importance as hibernation shelter in mild winters do not afford sufficient protection to be of the same relative importance in colder winters.

Studies on the direct control of the boll weevil have centered largely around improvement of dusting machinery and technic and comparison of different methods in different districts. The high-air-velocity dusters have been placed in extensive commercial use as far as the larger types of machines are concerned, and the same principle has now been incorporated in other types as small as the 1-mule duster. Experimental models involving the use of this principle have also been developed for riding, walking, and power cultivators. Some tentative types, particularly for use on power equipment, have reached the first steps of commercial production, but they must be developed still further before they can be placed in general use. The most important effect of this development is the increasing extent to which daytime dusting can be carried on. Machines are now available which permit successful control of the boll weevil with daytime operation in many districts where conditions are particularly favorable, and the present investigations are so improving the equipment and methods that it will soon be possible for other districts to dust their cotton in the daytime.

An increasing necessity for the use of insecticides in combination for the simultaneous treatment of two or more pests has considerably complicated the dusting-machine problem, and during the year much attention has been devoted to the calibration and modification of the older types of machines so that they can be used for the various combinations of calcium arsenate, nicotine, sulphur, Paris green, and other materials now being recommended for various applications. This has brought up new problems, such as that involved in the cohesion of mechanical mixtures of this sort, and has necessitated the study of the swath distribution of these insecticides applied in various mixtures from the different types of machines. For example, a material like Paris green has a tendency to separate from lighter, fluffier materials with which it is mechanically mixed, and when the two are blown into the air together the swath made by the Paris green is not so wide as that made by the lighter material. In some cases this condition has been remedied by the use of materials which increase the cohesion. Along with these studies other insecticides have been tested as usual, as well as various ideas of weevil control which are constantly being suggested. Special attention in both the laboratory and field-plot work has been devoted to such materials as the different fluosilicates and special grades of calcium arsenate supplied by the United States Chemical Warfare Service and others. So far, tests with none of these materials have progressed far enough to justify recommending their commercial use for weevil control, although in some instances results have been sufficiently favorable to warrant recommendations for use against other insects. For instance, the use of fluosilicates against the cotton leaf worm was developed as an incident in the studies and was particularly

advantageous during the season of 1929 at some points where there happened to be a shortage of arsenicals.

Plot tests of weevil control have been conducted every year at Tallulah for the past 14 years. The tests conducted last season showed that weevil damage for the year in that district was comparatively light, the average gain in pounds of seed cotton per acre in this series of tests being only 174 as compared with a maximum for the other years of 696. These figures are far below the average for the period of observation.

The cooperative investigations in South Carolina were again expanded slightly to include more studies of weevil flight and field activity and of some additional conditions in the poisoning tests. During the calendar year 1929 better results were secured from the early-season tests in South Carolina than in any preceding year and, because of the comparatively heavy damage prevailing, there was a very high average increase in the yield where the standard method of dusting was followed, the average gain for all tests being 666 pounds of seed cotton per acre. The regular weekly surveys throughout that State have been maintained, and the information obtained from them has been transmitted to the Extension Service for use in timely advice to the farmers.

The Oklahoma cooperative investigations showed quite a different picture from that of the preceding year. The initial spring infestation of weevils through the eastern half of the State was fairly heavy, following emergence from hibernation, and there was every indication that extensive efforts of control would be necessary. However, because of an extended period of exceedingly hot, dry weather, in only a few isolated localities did enough infestation develop to cause commercial damage. Research-plot tests were planned, as during the preceding year, at Hugo, Ada, and Muskogee. At the first two places natural control took care of the situation, and no poisoning was necessary. In Muskogee, however, in some of the bottom lands there was a greater degree of weevil activity and the plot tests in this district showed an increased yield from poisoning amounting to 444 pounds of seed cotton per acre. These studies combined with the regular weekly surveys made it possible to keep the State extension authorities thoroughly posted as to the progress or lack of progress of infestation in the different districts, and they in turn carried out a very intensive campaign, advising the farmers where it was necessary to poison and where it was not necessary to do so, thus enabling many farmers to save unnecessary expense. In connection with the extension workers' program some several hundred demonstrations of poisoning in various localities were carried out in such a way that considerable research information resulted. This will be of assistance when final recommendations for weevil control under the various conditions existing in that State are being worked out.

The unusually cold winter of 1929–30 in Oklahoma afforded the opportunity for some special observations on winter survival. Throughout much of the territory where boll weevils are normally most injurious in that State minimum winter temperatures ranging from −10° to −15° F. were experienced. Some 20 years ago, shortly after the weevil first reached that territory, similar winter conditions

prevailed, and consequently the weevil in the State was almost annihilated. In order to check up on the present effect of such a winter special attention was devoted this spring to the degree of infestation in the fields following emergence from hibernation. It was found that, in spite of the cold winter, a very fair average spring infestation resulted. Thus evidence additional to that obtained elsewhere that the weevil is tending to adapt itself to the more extreme climatic conditions has been secured.

Flight studies on the weevil have proved of such value in connection with control operations late in the season that these are now being standardized and included in the regular studies. The field observations on chemotropism have been combined with the flight-screen records and the attractants developed from the extracts of the cotton plant are exposed on some of these flight screens. To date these attractants, which seemed very promising under laboratory conditions, have not given such positive results in the field, but a considerable series of various mixtures, dilutions, etc., remains to be tested.

The plantation-control studies, dealing largely with the possibility of decreasing weevil infestation on property through fall and winter control measures, as well as general removal of hibernation shelter, are now showing rather definitely that the decreased amount of poisoning required quickly offsets the expense of these control measures.

COTTON FLEA HOPPER

Laboratory studies of flea-hopper damage have permitted some rather definite conclusions, and a preliminary report has been submitted for publication. More than a dozen species of hemipterous insects have now been definitely proven to cause this damage. Laboratory studies have failed to indicate the presence of any virus or organism transmitted by the insects, and the evidence to date indicates that the disturbance is brought about by some form of toxin, probably of a salivary nature, injected with the puncture. The fact that this damage is caused by numerous species made necessary the inclusion of all of these in complete life-history and biological studies as well as observations on their abundance and activity in various portions of the Cotton Belt. Observations are now under way throughout the season at various points extending from South Carolina to the arid West, giving the complete seasonal activity of all of these potential pests, in the cotton crop as well as on other host plants. Generally speaking, the true flea hopper, *Psallus seriatus* Reut., is the most important species concerned, particularly in the more western areas, but in the Mississippi Valley the tarnished plant bug frequently predominates, and in the Southeastern States some of the leaf hoppers apparently are most important. From a commercial viewpoint, damage from this cause was only of local importance during the season of 1929 except in the western portion of the Cotton Belt, and particularly in central Texas. Here the flea hopper was the most injurious pest of all, over a very large area.

Control studies have now been expanded to include numerous new forms of sulphur as well as other materials, particularly nicotine, which has yielded some rather promising preliminary results.

THURBERIA WEEVIL

The Thurberia weevil continues to increase in the areas of cultivated cotton where infestation had been reported previously, but fortunately no new areas of infestation were detected during the calendar year 1929. The studies of life history and biology have now started into the sixth year of continuous breeding on cotton, and a steady adaptation to the conditions of cultivated cotton is being noted. As a consequence, each year the same infestation in the spring results in a heavier ultimate damage to the crop. Because of the extent to which it still adheres to some of the habits acquired in connection with its natural host plant, however, its infestation can still be held below that which would result in serious injury, by such simple control measures as seed sterilization and winter clean-up.

PINK BOLLWORM

The pink bollworm research carried out in cooperation with the State of Texas has continued to expand rapidly. Among the more important results are those in connection with flight and movement, and one of the most interesting developments of the present season has been the establishment of the fact that the moths have a definite spring-flight period following emergence from hibernation as well as a similar late-season flight. The extent and duration of these flight periods are being determined by such means as flight-screen records and trap plantings. All evidence indicates the importance of the Laguna district of Mexico as a source of moths which may fly into the United States.

Studies of cultural control have yielded positive results. They indicate that a comparatively high mortality can be brought about by winter-control measures at very little expense. For instance, where plowing as deep as 4 inches can be followed within not more than two weeks by an irrigation of at least 6 inches, a mortality of from 97 to 100 per cent can be effected. Plowing without the irrigation is not nearly so effective but there are indications that it has some merit, and special studies on this subject are being conducted for the benefit of those areas where irrigation is not possible. The laboratory at Tlahualilo, Durango, Mexico, is being continued in operation and is devoting particular attention to the question of whether or not infestation can be maintained on host plants other than cotton. Several different host plants, notably okra and a species of wild Hibiscus, have very frequently been found to contain infestations, but so far this has occurred only in the presence of infestation in near-by cotton. In connection with any problem of possible eradication it is most important to know whether this species can maintain itself on these hosts in the absence of cotton. So far the evidence on this subject is negative, but it is by no means conclusive.

Methods and costs of destroying the pink bollworm in gin trash by burning and by steam heating have been worked out, but the most interesting results have been in connection with the grinding of this trash in some form of mill which will kill all insect stages present and still permit the later use of the trash. Sufficient progress has now been made to permit development of a mill that will handle a maximum of about 1,500 pounds of trash per hour with a requirement of approximately 5 horsepower and still grind the material

fine enough to kill all insect stages present. Such an experimental mill was set up in the Laguna district of Mexico, and even the coarsest grinding tested gave 100 per cent control of the insect stages. An interesting feature of this development has been the fact that this ground trash has a decided potential value. Even without special treatment it can be used either as a feed or as a fertilizer, and one large company which installed an experimental mill had no difficulty in disposing of some 15 carloads of ground trash at a price which made the operation financially attractive. Furthermore, there is very definite promise that, by developing a suitable separating system, lint of considerable value can be reclaimed and the residue of ground trash thereby greatly increased in value as feed stuff.

During the year the first importations of *Microbracon kirkpatricki* Wilkinson, a parasite of the pink bollworm which has brought about as high as 75 per cent control in the Kenya Colony of British East Africa, were made. Arrangements were made for the cooperation of the British entomologists, and two shipments were received in January and February, the second of which arrived in very good condition. Every effort is being made to perpetuate these insects and to arrange for further introductions until sufficient material can be bred for field release to determine the possible value of this parasite in the United States.

BOLLWORM

Still further emphasis has been placed on the bollworm investigations, and these have now been combined with the general cooperative study which is being carried out with the Texas Agricultural Experiment Station, with headquarters at College Station, Tex. In this study the bollworm receives the major attention, but along with it an effort is being made to develop suitable measures for dealing with the peculiar cotton-insect problems of that district, where two or more major pests are always present. Investigations during the season of 1929 disproved some disturbing ideas which had arisen during preceding years. For example, there has been some feeling that under certain conditions the use of arsenical poisons such as calcium arsenate increased rather than decreased the bollworm infestation, and therefore many farmers were afraid to poison for the boll weevil for fear of increasing the bollworm damage. This idea has been definitely disproven. Furthermore, an investigation to determine whether bollworm moths are attracted by the honeydew to fields heavily infested with aphids has also yielded negative results. At the same time, in tests carried out during the season of 1929 it was shown that the use of an arsenical poison did control the bollworm. Both laboratory and field-plot studies were conducted with various insecticides, such as arsenicals and fluosilicates. The best results on the average were obtained with calcium arsenate, although there is some indication that the addition of a slight quantity of Paris green to the calcium arsenate may be worth while. Special studies were conducted with Paris-green mixtures, both those mechanically mixed and those mixed wet during manufacture. So far the results indicate that the mechanical mixtures made at home are as good as the factory mixtures, but this point needs further verification. Tests to date have centered largely around a mixture containing 25 per cent of Paris green, but this is a rather high percentage for

commercial use, and current investigations are dealing with lower percentages. An interesting side light on the investigations of the season of 1929 in the Brazos bottoms near Bryan, Tex., was the fact that, while the first brood of bollworms on the cotton could be controlled by poisoning, the flea-hopper damage at that time was so great that there was little, if any, advantage from the destruction of bollworms, and it was not until the coming of the second brood that bollworm control actually brought about an increase in crop yield. In spite of this failure of the plants to take advantage of protection at the time of the first brood the bollworm damage was so heavy during the period of the second brood that the calcium-arsenate control plots still showed an average increase in yield from dusting of 418 pounds of seed cotton per acre. This was, of course, a season and a locality of unusually heavy bollworm damage.

INSECT MIGRATION

The question of migration and movement, whether only interfield or of an extended nature, is of prime importance in connection with so many cotton pests that this study has now developed into a broad one of the fundamentals involved in such activity. This is accomplished frequently in connection with the other investigations under way on the various pests and is brought about by such observations as infestation surveys, flight-screen observations, airplane collections, and field sweepings. The flight screens are being used in conjunction with so many pests and are yielding such important data that it is becoming obviously necessary to standardize the technic utilized. A very elaborate series of tests has therefore been inaugurated, involving screens at all altitudes from 3 to 50 feet from the ground, screens ranging from 1 to 10 feet square, and screens of different shapes, as well as coated with various grades of adhesive material. So far there has been some indication that the shape of the screen and the presence or absence of possible air eddies may have a definite influence on the results secured, particularly in connection with the flight studies of the pink bollworm. The flea-hopper studies, particularly in Texas, indicate increasingly that the problem in many sections is dominated by the question of flight or air movement. The same applies to other pests, notably the bollworm and the leaf worm.

COTTON LEAF WORM

Studies of the cotton leaf worm have dealt largely with the factors influencing the direction and distance of its movement as well as with the possibility of preventing or at least retarding its spread through the United States by control measures in southern Texas where it first appears each year. During the growing season of 1929 commercial control activities in southern Texas retarded spread over the other cotton areas by not less than two months, and this permitted growing a successful crop in many districts before the leaf worm arrived. Another interesting feature of that season was the fact that while the moths of the September generation, which normally become most widespread of all, were most active, the prevailing winds were from the north; as a result, there was much less migration northward than normally.

COTTON APHID

The cotton louse has continued to receive considerable attention, especially in connection with the development of infestations following poisoning. Recommendations for dealing with this situation have been rather definitely worked out, and a popular publication has been issued on the subject as well as more technical publications dealing with the factors concerned. It is now found that by the addition of sufficient nicotine sulphate to give a 2½ per cent nicotine content to the calcium arsenate used for weevil control complete commercial control of the louse can be brought about in almost every instance by a single application.

COTTON LEAF PERFORATOR

The cotton leaf perforator, which has attracted particular attention in the Imperial Valley of California, was especially injurious during the season of 1929, and it has been necessary to reopen this investigation on a more elaborate scale than before. Some of the control studies have indicated the possibility of bringing about a comparatively high degree of larval mortality with the use of arsenical insecticides, and one especially interesting development was the fact that an adult mortality of over 70 per cent was noted to follow the use of nicotine dust. These studies now include all phases of life history, biology, and activity, as well as control tests.

MISCELLANEOUS INSECTS

In addition to the foregoing major problems it has been necessary to devote the usual amount of attention to the outbreaks of other cotton insect pests that have occurred from time to time. These have involved such pests as grasshoppers, crickets, cabbage loopers, salt-marsh caterpillars, and numerous others. Whenever these outbreaks occur and can possibly be reached special studies are conducted on the nature of the infestation, and such control measures are tested as seem justified under the circumstances.

TROPICAL, SUBTROPICAL, AND ORNAMENTAL PLANT INSECTS

The work under this heading has, as formerly, been under the direction of A. C. Baker.

MEDITERRANEAN FRUIT FLY

The subject of particular interest in this field has had relation, as last year, to the occurrence of the Mediterranean fruit fly in Florida. The experimental work which falls under the field of this bureau in relation to this newly introduced pest was discussed with some fullness in the report for 1929; namely, (1) the development of effective sprays and (2) of attractants for the adult fly; (3) a survey of the wild fruiting plants in the infested territory; (4) determination under cage conditions of the susceptibility of such wild fruits to fly attack, as well as of any cultivated fruits grown in Florida the fruit-fly status of which was unknown; and (5) the determination of methods of treatment of fruit or vegetables which can be

relied upon as eliminating the risk of distribution of this pest to other parts of the country by movement in commerce of such articles.

As a result of the intensive spraying and other control measures which were used in the invaded area the fly practically disappeared from Florida in August of 1929, the last finding of adult flies in that year having been on August 27 and the last finding of larvae (four in one orange) on November 16. Since that time two very light infestations have been discovered. On March 4, 1930, several larvae were found in two fruits on one sour-orange tree near Orlando, and on July 25, 1930, two pupae were found in soil under a sour-orange fruit in a dooryard in St. Augustine.

In view of the practical absence of the fly, it was deemed desirable to discontinue work with living material in Florida, and the 1st of March, 1930, arrangements were made to conduct any further tests involving such material in Hawaii. The rounding up of other work in Florida concerned particularly the completion of the tests relative to the different types of sprays and of attractants and bringing to a conclusion the wild-fruit survey and the testing of such fruits as to susceptibility to fly attack.

In the course of the wild-fruit survey it was found that 43 fruits occurring more or less widely in the State could serve to propagate the insect and continue infestation. Eight of these were state-wide in their distribution, 6 were distributed throughout the peninsula of Florida, 11 were confined to the upper half of the State, 2 were distributed in the central peninsular region, 3 occupied the entire coastal area, 10 were confined to the lower half of the coastal area, and 3 were rare and reported only locally. These findings indicated the difficulty which would attend any eradication effort should there have been a general infestation of such wild hosts. Very fortunately the surveys indicated no such wild-host infestation. On the other hand, in the wild land, such as hammock areas, where citrus groves had been planted, there were many instances of the fruit fly having reached such groves, many of which were growing under hammock and other conditions similar to that of the wild hosts. The explanation apparently is that the human contact was frequent and regular with such plantings, involving the transfer in some instances of picking crates, citrus fruit, and other means for carriage of larvae and pupae of the fly. There would seem, therefore, to be little basis in the mere location in hammock or similar wild-land areas to give immunity to wild fruit from infestation.

The further study of poison-bait applications for adult flies has confirmed the practicability and usefulness of copper carbonate [1] as a substitute for arsenical poisons, and this new spray was utilized widely during the season of 1930 by growers and others in interest throughout the old infested portion of the State.

The work with traps to measure the effectiveness of spraying, and more particularly as an aid to inspection by indicating the presence or absence of the fly, has been continued in the hope of finding a more efficient attractant. Ordinary coal oil or kerosene has continued, however, to be the most satisfactory attractant, and while only males

[1] Copper carbonate bait spray for the Mediterranean fruit fly: The bait spray developed in 1929 and now recommended for general use has the following formula: Copper carbonate, 8 pounds; sirup (blackstrap), 5 gallons; sugar (soft brown), 25 pounds; water to make 200 gallons. This spray is recommended for use at the rate of 1 pint for eight trees or about 1 gallon per acre.

were attracted to traps thus baited the fact of the occurrence of the sexes in about equal proportions makes the collection of males a satisfactory measure of the abundance or even presence of the insect.

The experimental work to determine the relative susceptibility of different host fruits and vegetables was continued and covered the more important Florida products. This work indicated that there was practically no risk, under conditions of culture employed in Florida, attaching to string beans and cowpeas and that the risk as to certain other vegetables known to be occasionally infested was very remote. Accordingly, these various vegetables—i. e., string beans, cowpeas, and also pumpkins, gourds, squashes, and cantaloupes—were released from all restrictions for production and shipment. In the revised quarantine, effective September 1, 1929, certain restrictions and safeguards still applied to peppers, tomatoes, eggplants, and broad and Lima beans.

The research work involving living insects, elsewhere referred to as transferred to Hawaii, has dealt largely with the question of securing more information on the sterilization of fruit and vegetables by either heat or cold—methods which were described in the report for 1929.

The method by refrigeration, while entirely successful and practicable, and actually utilized very largely as to the crop of 1928–29 in commercial movement of fruit, nevertheless called for accuracy of handling to prevent the overcooling and possible freezing of fruit. It will be remembered that the refrigeration required in connection with the crop of 1929 called for subjection of the fruit to a temperature of 28° F. for five hours and thereafter the holding of such fruit for four and one-half days at 30°. This treatment gave complete mortality to the fruit-fly larvae and, when properly conducted, no injury to the fruit. In view, however, of the risk of freezing the fruit, it seemed highly desirable to determine what could be done with temperatures at or above freezing point. Some rather extensive experimental work in this direction was conducted in Hawaii during the winter and spring of 1929–30, and without exception it was found that a temperature of 30 to 31° for 15 days was fatal to any eggs or larvae that might be present in the fruit. These temperatures are well within the range of standard cold-storage practice and can be easily maintained without risk of freezing, and this new method was adopted toward the end of the last shipping season in the spring of the current year and will hereafter be available for general commercial practice.

MISCELLANEOUS SUBJECTS

The work of the Division of Tropical, Subtropical, and Ornamental Plant Insects covers a number of other very important projects. Some of the outstanding developments of the season as to these projects are briefly indicated below.

The research work on the Mexican fruit worm has been continued in the laboratory in Mexico City. These studies have been concerned more particularly with the biology of the insect and its reaction to temperature and other conditions of environment. The temperature response is the subject of a paper which has been prepared for publication. A special study of parasitism through a full year period has been completed, and in connection with other work a high

mortality of adults has been secured from the use of copper compounds in line with similar results obtained with the Mediterranean fruit fly in Florida.

The very important international project concerned with the importation of parasites of the citrus black fly into Cuba, carried out in cooperation with the Cuban Department of Agriculture, is reaching what promises to be a very successful conclusion. The first shipment of parasites, *Eretmocerus serius* Silv., arrived April 21, 1930. Several generations of these parasites have now been reared in Cuba, and recoveries are being made from colonies established in the field. Mr. Clausen, who has been in charge of the parasite studies and collections in the general Singapore district, is now en route to America with a considerable shipment of parasites and predacious insects of various types. Preparation for the handling and distribution of these parasites has already been made. It is hoped that the insects in these shipments, together with the parasite above referred to, will prove to be very efficient natural controls for the black fly in Cuba and be available for colonization in Florida should the black fly become established there.

Work on bulb pests has been continued at the laboratory at Sumner, Wash., at the new laboratory in Whittier, Calif., and at the new laboratory at Babylon, Long Island, N. Y. At these laboratories work has been conducted on the perfecting of fumigation methods. Also, in relation to this work, the new heat or vapor method of sterilizing citrus fruit, developed at the Florida laboratory in connection with the research on the Mediterranean fruit fly, has been applied experimentally and successfully to bulbs and also to ornamental plants in full leaf. The results are promising as offering a means of sterilizing bulbs, and plants in foliage, without injury. Moreover, the vapor method is cheap, permits handling in large quantities and in various types of containers, and the subsequent drying of the product. For experimentation on a commercial scale, sterilization plants of this type have been installed in the laboratories at Sumner and Babylon.

At the New Orleans laboratory, as in the past, the major effort has been devoted to the study of oil emulsions as sprays for the control of scale insects. Several phases of this work have been completed, and manuscripts are being prepared for publication. These cover three rather distinct problems: (1) Natural mortality and seasonal development as they influence control studies; (2) the effect of population density on kill; and (3) the relative susceptibility of different developmental stages. On the physical-chemical aspects of the emulsion studies three reports have been completed, one covering characteristics of fish-oil soap, one dealing with the properties of dilute emulsions, and one covering general methods and emulsion preparation.

One of the important undertakings of the year has been the completion and equipping of the laboratory at Whittier, Calif., for necessary work particularly in the citrus field. This laboratory was made possible by the interest of the citrus industry in California which financed its construction following special plans prepared by the bureau for the work to be undertaken. It is a 3-story structure, is equipped with refrigeration plant, constant-temperature rooms, and other special features, and is provided with 2 acres of land for experi-

mental plots. The major projects which are now under work at this laboratory concern the determination of more efficient methods of control, particularly of important citrus scale insects, both by fumigation and by spray applications. This laboratory, however, will be headquarters for practically all of the work of southern California in relation to citrus and other subtropical insects, including bulb insects.

INSECTS AFFECTING FOREST AND SHADE TREES, INCLUDING THE GIPSY MOTH AND THE BROWN-TAIL MOTH

The work in this field has been continued, as formerly, under the direction of F. C. Craighead.

WESTERN BARK BEETLES

Epidemics of the western pine beetle, which started in 1924 in the pure yellow-pine stands of northern California and caused a loss of 670,000,000 board feet of stumpage on 320,000 acres during the five succeeding seasons, underwent a sharp decline in 1929. The volume of yellow pine killed during the season of 1929 was 80 per cent less than in 1928. However, even with this reduction the 1929 losses were three and one-half times as great as those which occurred in 1923, the season before epidemic conditions started. The improvement was apparently due to better growth conditions in the forest during the season of 1928 and to a great increase during the same season in the number of natural insect predators of the beetle. This decline from natural causes was not general, however, as in the southern part of the Sierras the season of 1929 was marked by a decided tendency toward an increase of this insect.

Control operations during 1929 in California were financed mainly by owners of private timber. One company treated 2,320,000 board feet on an area of 20,000 acres in Modoc County. This control campaign was combined with salvage logging of the infested timber and will be followed in the near future by logging of the more susceptible green timber on the area. This type of selective logging is something of an innovation in dealing with bark-beetle infestation and is designed to save, through utilization, reserves of merchantable mature timber by manufacturing into lumber those trees which are apt to be killed by the beetles.

In southern Oregon the decline in the losses of western yellow-pine timber from the activities of the western pine beetle, which was first noted in the fall of 1928, continued during the season of 1929. The destruction of timber dropped to less than half of that in 1928. This was largely due to an improvement in moisture and growth conditions throughout the forested area. In spite of the natural improvement in conditions the Forest Service, the Indian Service, and private timber-owning corporations continued to combat the pine beetles with artificial control measures, concentrating their efforts on areas which had not responded readily to the natural decline. Approximately $56,000 was spent in this work.

A survey was also made of the lodgepole-pine stands of Crater Lake National Park, Oreg., which have been suffering badly from attacks of the mountain pine beetle, and where control operations to protect the more valuable scenic and roadside areas around the

park headquarters have been conducted under the supervision of the bureau during the past four years. It was found that the control work had been very successful in reducing the losses in the treated areas, but that these areas were still menaced by epidemic centers in the surrounding country. This protective work will be continued by the park service during the coming year.

The surveys of sample plots distributed through the region, which were started in 1921, were continued through the year. It is expected that these surveys, covering, as they do, a wide area, will ultimately furnish valuable information on the correlation of bark-beetle epidemics and weather factors.

During the season of 1928 a small center of infestation of the mountain pine beetle was discovered in lodgepole pine in one of the important public camp grounds of the Sequoia National Park. In the fall of that season 44 infested trees were treated by the National Park Service. During the season of 1929 only three trees were attacked within the area. This project, though small, again demonstrated the feasibility of controlling this beetle where a complete clean-up of the infestation within the locality is accomplished. In this case there were no large areas of infestation within a distance of several miles to reinfest the treated area.

In the spring of 1929 approximately $25,000 was spent by the Forest Service in conducting artificial-control measures within the white-pine stands of the Coeur d'Alene and Kootenai National Forests for the reduction of mountain pine beetle outbreaks. The results secured from these projects were very satisfactory. In October $6,100 was spent on the Kootenai in an initial effort to test the practicability of fall control against the mountain pine beetle. The primary purpose of this project was to obtain a comparison of cost and effectiveness between fall and spring operations. The results secured were satisfactory and warrant further tests of fall control. It is thought that the better working conditions encountered in the fall will bring about a considerable saving.

Artificial-control measures for the suppression of an increasing outbreak of the mountain pine beetle in the lodgepole pine stands of the Targhee, Teton, and Wyoming National Forests were carried out by the Forest Service under the supervision of the Bureau of Entomology. The seriousness of this situation lies in the fact that these forests are continuous with those of the Yellowstone National Park and that an epidemic within the region would undoubtedly result in the destruction of the timber stands of the park. Some 40,000 trees were treated, and a satisfacory reduction in the infestation followed. However, all of the infested areas were not covered, and it was necessary to clean up the remainder last spring. In connection with this project the Forest Service has developed a rather novel method of treatment which is especially adapted to the open forests of that region. Inflammable oil is sprayed upon the infested portion of the tree trunk and the trees are burned standing. The heat which is produced from the charring of the bark is sufficient to destroy the insect broods beneath. Surveys of the white-pine stands of northern Idaho and western Montana show that serious epidemics of the mountain pine beetle are developing. A large-scale control operation will be conducted on the Coeur d'Alene National Forest in the spring of 1930, which will be the largest

forest-insect control project ever attempted. Smaller projects of this nature will also be carried out on the Clearwater and Kootenai National Forests, as well as in the Glacier National Park.

Intensive studies on the mountain pine beetle in Montana have contributed toward a better understanding of the relationship of parasites and predators. From the information gained it is now known that control work conducted in the fall of the year contributes toward the preservation of the most beneficial of these parasites, and this may result in a uniform adoption of fall control instead of spring operations during which most of these parasites are destroyed. Studies to determine the effects of artificial control and to devise improvements, and to determine the relation which fire-scorched trees bear toward the building up of subsequent bark-beetle epidemics, have been continued during the year.

One phase of the investigations dealing with the western pine beetle has been centered upon the food materials which this insect utilizes in western yellow pine, and the changes in this material that render certain trees attractive to the beetle. This study will require further development before conclusions can be drawn; but it has already been found that definite chemical changes, which take place in materials in phloem after a tree is felled, make it attractive to the beetles. Similar conditions have been observed in slow-growing trees before they are cut, which apparently accounts to a large extent for the preference shown by the beetles for trees of slow growth.

Considerable progress has been made during the year in the study of the biology of those insects associated with the western pine beetle. One species, a clerid, has been definitely established as an important predator of the adult bark beetle and its larva. It has also been found that infested bark can be exposed to the sun so as to kill the western pine beetle by solar heat, but that at the same time the predators will escape by moving out of the bark and complete their development. It seems possible, therefore, to apply biological control by reducing the numbers of bark beetles, at the same time preserving the numbers of their predators. During the coming season it is proposed to make an actual test of this method of control on an experimental basis.

THE FIR ENGRAVER

This insect (*Scolytus ventralis* Lec.) during the past five seasons has caused widespread injury to white fir throughout the Sierra Nevada region. During the spring of 1929 an analytical study was made of the character of the damage on three mill-scale study plots on the Stanislaus National Forest. It was found that a high percentage of the trees which are top killed have been attacked by this insect, and that it was responsible for the complete killing of trees of small diameters. This is at present the most important insect pest of white fir on cut-over lands and will undoubtedly have to be reckoned with in the management of stands containing a high percentage of this tree.

THE SOUTHERN PINE BEETLE

Additional data were secured emphasizing the close relation which exists between climatic conditions and beetle abundance. In the Appalachian region, following a mild winter, the beetles were abundant

during the early spring of 1929, and a rather heavy emergence was anticipated. An unexpected excess in precipitation during April and May, amounting to 5.4 inches in some localities, and coming just as the beetles were emerging, resulted in their sudden disappearance, so that by June 15 hardly a beetle could be found. This was followed by a deficiency during July and August amounting to 3.34 inches around Asheville, N. C. Simultaneously reports of outbreaks began to come in as others were found in the surrounding forest. Many weakened, lightning-struck, or wind-thrown trees were found infested, and as a result beetles were attracted to surrounding trees and infestations were built up. Severe infestations were located in the Pisgah and Unaka National Forests. The largest outbreak occurred at Hot Springs, N. C., in the French Broad division of the Pisgah Forest. Here, during September, some 2,716 old-field pines were found attacked on an area of about 30 acres.

A large number of beetle-infested trees were injected with poisonous solutions to determine the possibility of controlling bark beetles by this method. Complete mortality of the broods was obtained with a number of chemicals when injected into recently attacked trees. The condition of the tree at the time of injection was found to be of the utmost importance. The injection had to be made before the blue stain, associated with the bark beetle, had extended into the sapwood. When blue stain was present injections with the same chemicals, using two to three times the strength of dosage, failed to give very satisfactory results.

THE LOCUST BORER

Studies relating to the control of the locust borer (*Cyllene robiniae* Forst.) by spraying were continued. Dilutions of solutions found effective the previous year were tried and were highly successful, as a result of which the cost of application has been lowered. Arsenical sprays, orthodichlorobenzene emulsion, orthodichlorobenzene and kerosene, and a paradichlorobenzene-pine-tar emulsion were used.

THE PINE TIP MOTH

Studies were continued on the parasites of the pine tip moth in the extensive Forest Service plantations at Halsey, Nebr., where this pest has been seriously retarding the growth of young pine trees for the last 20 years. *Campoplex frustranae* Cushman, a parasite introduced from Virginia in 1925, showed a continued increase and is now getting the tip moth under control. During the season of 1929, in the vicinity of its original release, parasitism amounted to about 82 per cent, four-fifths of which was due to this introduced species. Rearings showed the parasite to have reached a point in numbers above that of the host. The reduction in the number of infested tips and the benefit to the trees were very noticeable, only 33 per cent of the terminal shoots of yellow pine being infested as compared to about 90 per cent in previous years, and many of these trees had normal terminal shoots for the first time in many years. The parasite has spread satisfactorily and reached the limits of the plantation some 4 or 5 miles distant, where it will take several years for it to build up in sufficient numbers to bring about control.

THE WHITE-PINE WEEVIL

Cooperative studies on the white-pine weevil begun in 1924 with Harvard Forest and the Northeastern Forest Experiment Station were brought to a close in 1929 with the publication of the results of this work as Technical Publication 28 of the New York State College of Forestry, Syracuse, N. Y. Considerable new information on the biology of the insect is given and practical methods for growing white pine so as to avoid injury by this serious pest are described. Permanent sample plots laid out during these studies will be kept under observation for a number of years in order to check finally under actual growing conditions the ultimate effectiveness of the practices recommended, and to secure data for further correlation on the annual prevalence of the injury and seasonal conditions.

THE LARCH SAWFLY

The study of the larch sawfly has been continued during the year in the Lake States region, both in the vicinity of Ann Arbor, Mich., and in and about Itasca Park, Minn., through cooperation of the School of Forestry, University of Michigan, with S. A. Graham acting as agent. Some new biological information has been obtained. It has been found that insects which have suffered from scarcity of food during the larval period do not produce so large a number of eggs in the adult stage as do those that are well fed during the developmental stages; also, that the number of eggs laid by a female depends to a considerable degree upon the stage of development of the tamarack at the time of oviposition. Unless the new growth is one-half inch or more in length the sawflies refuse to lay their eggs even though they may die without ovipositing. The number of eggs laid increases in proportion to the length of the new growth until a length of about 6 centimeters has been reached, but after this point there seems to be no further increase.

The permanent sample plots were examined as in previous years. It is hoped that these examinations can be continued for some years to come to obtain information on the effect of defoliation and annual abundance of the insects. The growth appears to be reduced in direct proportion to the degree of defoliation. The curves representing the annual increment in the various groups follow lines which would naturally be expected, except in those trees which were completely defoliated for three years in succession. These show a considerable acceleration of growth the first year of defoliation, followed by a rapid decline, and death at the end of the third year.

THE BRONZE BIRCH BORER

Study of this insect initiated two years ago in cooperation with the Northeastern Forest Experiment Station and the University of Michigan was carried on in New Hampshire last year. One important point was brought out by these studies; that is, the apparent importance of environmental factors and the shoe-string fungus. It appears that the death of the birches following logging operations can be attributed entirely to Agrilus, but that the changes in soil temperature and moisture, and the shoe-string fungus (Armillaria), may be equally or more important factors than Agrilus.

INSECTS AFFECTING FOREST PRODUCTS

In cooperation with the termite investigations committee of the University of California, additional preservatives were placed under test at Panama during 1929 and 1930, in the long-time tests of wood-preservative treatments for both crude and finished forest products, and poisons for wood pulp and fiber products to prevent insect attack were also tested. The international termite-exposure tests, in cooperation with the Forest Products Laboratory, begun last year, have already furnished interesting results, reports from government officials in South Africa, Hawaii, and Panama showing a remarkable uniformity in at least preliminary results, considering the different conditions of exposure. The termite-proof buildings constructed of treated timber, as a supplement to these wood-preservative tests, are still proving satisfactory. Tests of mortars for foundation walls are being continued at Urbana, Ill., and Cleveland Park, Washington, D. C., in cooperation with the University of Illinois and the United States Bureau of Standards, to determine the best type of mortar to prevent entrance of termites through the foundation walls.

By the advice of the Bureau of Entomology, provisions to prevent termite attack have been included in mandatory city building codes in various cities in continental United States, as well as in the Canal Zone, Panama, and the Territory of Hawaii.

A film strip to illustrate graphically Department of Agriculture Leaflet 31 has been prepared and is available for the use of State entomologists in demonstrating how to render buildings termite-proof.

A publication has been issued by the National Committee on Wood Utilization advocating the retail sale of treated timber and its greater use in the construction of buildings. In this the Bureau of Entomology has contributed a chapter on wood-destroying insects.

Wooden articles, such as gunstock blanks, in storage at large arsenals in Illinois, Pennsylvania, and Massachusetts, were inspected at the request of the War Department, to prevent accumulative damage by powder-post beetles. The War Department requests that in the future such inspections be made by the Bureau of Entomology every two years.

The Bureau of Entomology has recommended dry Paris green as a remedy for the nonsubterranean termites which have been killing large numbers of tea trees in Ceylon. This method has proved very effective in saving the trees.

SHADE-TREE INSECTS

As in former years, the activities under the shade-tree insect project have necessarily been confined largely to the dissemination of information. Each year the demand for this service increases and the general aid through correspondence has been supplemented by radio talks, newspaper articles, and timely articles in other popular periodicals. A small increase for the coming fiscal year will make it possible for the bureau to extend its efforts in these problems to California and other States of the extreme West.

GIPSY MOTH AND BROWN-TAIL MOTH

FOREIGN WORK

The foreign work has included field investigations in Yugoslavia, Hungary, and Poland, biological studies on certain parasites of the gipsy moth and the satin moth, and the shipment of parasites from these central European countries to the gipsy-moth laboratory at Melrose Highlands, Mass. Two entomologists have conducted this work, with headquarters at Budapest, Hungary. About 100,000 parasites were sent during the summer of 1929 from the countries mentioned. Most of the parasites were various species of tachinid flies. About 4,100 cocoons of a species of Meteorus, bred from the satin moth, were received, and the adults emerging from these were liberated in New England.

Of the 30,000 cocoons of the hag moth (*Cnidocampa flavescens* Walk.) received from Japan early in the spring of 1929, 6,190 adults of *Chaetexorista javana* B. and B. emerged, and 4,547 adults were liberated in the vicinity of Boston. There are on hand at the gipsy-moth laboratory at the present time 779,000 cocoons of *Cnidocampa flavescens*. At the time this report was being prepared the parasites had not emerged from this material, but dissections indicated parasitism of about 25 per cent.

Investigations are being conducted in Sweden and other northern European countries to locate an infestation of *Phyllotoma nemorata* Fall., a sawfly that was introduced into Maine and has spread into New Hampshire and Massachusetts. The object is to secure parasites for introduction into those States.

STUDIES AND COLONIZATION OF PARASITES AND PREDATORS

During the fiscal year over 3,125,000 parasites have been liberated in the field, about 2,900,000 of these being *Anastatus disparis* Ruschka. One of the important liberations in large numbers in 1930 was the fly *Phorocera agilis* R. D., from overwintering material received from Europe in the late summer of 1929. Liberations were made of fertilized females and of gipsy-moth larvae upon which eggs had been deposited by fertilized females. This species was recovered in 1929 at a point where it was colonized in 1928, indicating that success has been attained in establishing this parasite after the attempts of several years.

The tachinid *Sturmia inconspicua* Meig., a parasite of sawflies and the gipsy moth, was recovered in 1929 in the same locality where it was liberated in 1928. *Chaetexorista javana* also was recovered in the late summer of 1929 in dissections of host material collected where the flies had been liberated earlier in the season, indicating that this species also is established. Records for 1930 will further verify this recovery.

Of the old-established parasites of the gipsy moth, *Anastatus disparis* Ruschka, *Ooencyrtus kuvanae* Howard, *Sturmia scutellata* R. D., and *Compsilura concinnata* Meig. show an increase over the previous year. *Calosoma sycophanta* L., the predatory beetle, has also increased generally.

The parasitism in the winter webs of 1929–30 of the brown-tail moth showed a general increase over that of the previous year. The

parasites contained in these stages are *Compsilura concinnata* Meig., *Meteorus versicolor* Wsm., *Zygobothria nidicola* Towns., and *Apanteles lacteicolor* Vier. Adults of *Eupteromalus nidulans* Foerster were also found to be more abundant in the hibernating webs of the brown-tail moth, and this is partially explained by its increased parasitism of the satin moth in the same locality. The parasitism obtained from the full-grown larvae of the brown-tail moth in 1929 was considerably less than that obtained the previous year.

The Calosoma beetle traps were tried on a rather large scale during the season of 1929, when a total of 17,332 were collected in fourteen ¾-acre plots; 2,576 traps were placed out, which indicated an average of 1,175 beetles per acre, or 6.7 per trap. An average of 174.6 traps were placed out to the acre. The largest number of beetles obtained in 1 acre was 4,220. Each trap in this area collected 22.9 beetles during the season.

The beetles were used for recolonization purposes in central and western Massachusetts to study their effect in new territory where the host infestation is light but increasing, and some were sent to other States, as follows: 2,000 to Raton, N. Mex., to be colonized as an enemy of the New Mexico range caterpillar; 300 to Alamogordo, N. Mex., to be colonized as an enemy of the fir tussock moth; 200 to Seattle, Wash., to be colonized as an enemy of the satin moth.

BACTERIAL AND FUNGOUS DISEASES

An attempt was made in 1929 to recover the bacterial disease of the gipsy moth *Streptococcus disparis* Glaser, but with negative results. Studies were conducted at the same time of the wilt disease of the gipsy moth, which was generally prevalent and effective. An attempt is being made in 1930 to again introduce the Japanese gipsy-moth fungous disease of the family Entomophthoraceae. Studies of the fungous diseases of the satin moth, namely, (*Sporotrichum*) *Beauveria globulifera* Speg. and *Isaria* sp., were conducted during the season of 1929 to establish the status of these fungi, which are both parasitic and saprophytic on this host.

ATTRACTANTS

The attraction experiments with the gipsy moth are being continued. These consist of attempts to find a better extract than benzol, xylol, or gasoline for the preservation of female genitalia which are later exposed in the field to attract males. A limited use has been made of this method in the field as a check on scouting work.

INSECTICIDES

Spraying investigations with lead arsenate and fish oil used as a sticker were conducted in 1929 in eighteen ½-acre plots in heavily infested woodland. Half of the plots were treated with lead arsenate alone and the other half with lead arsenate-fish oil mixtures and sprayed at different periods. The results indicated that 4 pounds of lead arsenate to 100 gallons of water, with 4 ounces of fish oil added to each pound of poison, was effective for the control of larvae in the earlier stages and even gave a good degree of control

for the later stages; but for late spraying, when the larvae were in the fourth or later stages, the results indicated that 5 pounds to 100 gallons of water was more effective.

Some tests were made during the year to determine the quantity of poison deposited on the leaves in woodland spraying and that falling on the ground. Two plots of 1 acre each were sprayed, and these indicated that 35.4 and 21.1 per cent, respectively, of the poison fell on the ground and 64.6 and 78.9 per cent was deposited on the foliage. From these two plots the quantity of foliage per acre was computed from samples after analysis of the lead arsenate was made, indicating that the first plot contained 5 acres of foliage and the second plot 8.3 acres, an average of 6.65 acres for the two plots.

Experiments were continued during the year in controlling the satin moth on Carolina poplars, these being sprayed with 4 and 5 pounds of lead arsenate to 100 gallons of water, with fish oil added as an adhesive. A dosage of 5 pounds to 100 gallons, to which fish oil was added, proved to be the more reliable in that it was desired to have the poison remain on the foliage from June, at the time the spring generation of larvae was feeding, till July and August, when the newly hatched larvae from the next generation fed before spinning cocoons for hibernation later. The tests showed that as an average only 13 hibernating larvae per square foot were found in burlaps used as traps on the trunks of the sprayed trees, against 530 hibernating larvae per square foot in burlaps on the check trees. A manuscript has been prepared setting forth these results in detail.

Dusting experiments have been conducted during the year with the idea of developing a sticker for poison dusts. Twenty-five dust mixtures containing lead arsenate or calcium arsenate as the arsenical were tested. Eleven of these mixtures gave promise of greater adherence than lead arsenate alone. Some of these were:

Lead arsenate, 80 per cent; bentonite, 20 per cent;
Lead arsenate, 80 per cent; ferric oxide, 20 per cent;
Lead arsenate, 50 per cent; activated carbon, 50 per cent;
Lead arsenate, 83 per cent; fish oil, 10 per cent; water, 7 per cent;
Lead arsenate, 20 per cent; bone black, 80 per cent;
Lead arsenate, 70 per cent; calcium chloride, 20 per cent; fish oil, 10 per cent.

Foliage-injury tests with arsenicals were continued during the season of 1929. These showed that injury took place much more readily from the under surface of the leaf and that moisture was necessary. A histological study of injured and uninjured leaf tissue was begun, which indicated that the arsenical penetrated through the cuticle instead of the stomata of the leaf. A mixture of 2 parts lead arsenate, 3 parts lime, and 3 parts ferrous sulphate gave promise of decreasing the solubility of the arsenic, and as a spray it adhered as well as or better than lead arsenate alone.

Toxicity experiments were conducted in 1929 with gipsy-moth larvae in which lead arsenate, calcium arsenate, and white arsenic were used. Each of the arsenicals gave a different toxicity ratio, depending in part on the percentage of arsenic which broke down in the digestive tract. The possibility of an enzyme acting on the arsenical was suggested.

Defoliation by the brown-tail moth was extensive in southeastern New Hampshire and a small portion of southwestern Maine in 1929,

as for several years past. A rough survey of this area indicated that a total of 16½ acres was defoliated, 7½ being in New Hampshire and 9 in Maine. Apple and wild-cherry foliage in this area was heavily fed upon. In addition to this several local infestations of small areas were known to exist in the coastal region of Maine and the eastern section of Massachusetts.

The acreage affected by the gipsy moth in New England in 1929, as estimated by employees of the Plant Quarantine and Control Administration, in cooperation with the States concerned, is as follows: 171,107 acres had from 1 to 50 per cent defoliation and 380,026 acres had from 50 to 100 per cent defoliation. Acreage affected in 1929 showed a considerable increase over that affected in 1928, a large proportion of this increase being in New Hampshire.

INSECTS AFFECTING STORED PRODUCTS

The investigations of stored-product insects have been conducted, as formerly, under the direction of E. A. Back.

NEW GRAIN FUMIGANT

The outstanding feature of the work with insects affecting grain and grain products has been the development of a new method of fumigating wheat in large terminal elevators. It is gratifying to report this distinctly new addition to our knowledge of insect control in bulk wheat at a time when grain elevators the country over are filled to capacity with a crop showing considerable weevil infestation.

In last year's report reference was made to the discovery of the value of ethylene oxide as a fumigant and to the fact that the mixture of certain fumigants with carbon dioxide enhances their insecticidal value. The insecticidal value of ethylene oxide was first discovered by R. T. Cotton, of the Bureau of Entomology, and R. C. Roark, of the Bureau of Chemistry and Soils, who published an account of their experiments with it in 1928.[2] Doctor Cotton and H. D. Young, of the Bureau of Chemistry and Soils,[3] found that by mixing carbon dioxide with ethylene oxide the toxicity was considerably increased and the fire hazard reduced or eliminated according to the proportion of carbon dioxide used. Further tests by E. A. Back, R. T. Cotton, and G. W. Ellington, all of the Bureau of Entomology,[4] indicated the desirability of using at least 7 pounds of carbon dioxide with 1 pound of ethylene oxide. Jones and Kennedy,[5] of the Bureau of Mines, found that the vapor formed by a mixture of 7.15 parts by weight of carbon dioxide with 1 part of ethylene oxide was noninflammable.

For some years the Bureaus of Entomology and Chemistry and Soils have been searching for a fumigant suitable for use in the

---

[2] COTTON, R. T., and ROARK, R. C. ETHYLENE OXIDE AS A FUMIGANT. Indus. and Engin. Chem. 20: 805. 1928.

[3] ——— and YOUNG, H. D. THE USE OF CARBON DIOXIDE TO INCREASE THE INSECTICIDAL EFFICACY OF FUMIGANTS. Ent. Soc. Wash. Proc. 31: 97–102. 1929.

[4] BACK, E. A., COTTON, R. T., and ELLINGTON, G. W. ETHYLENE OXIDE AS A FUMIGANT FOR FOOD AND OTHER COMMODITIES. Jour. Econ. Ent. 23: 226–231. 1930.

[5] JONES, G. W., and KENNEDY, R. E. EXTINCTION OF ETHYLENE OXIDE FLAMES WITH CARBON DIOXIDE. Indus. and Engin. Chem. 22: 146–147, illus. 1930.

treatment of stored grain. On account of fire hazard, excessive cost, ineffectiveness, toxicity to man, or deleterious effects on grain the fumigants in general use up to the present time have not been entirely satisfactory and the operators of grain elevators have had to resort to handling the grain in order to keep it in condition.

With the crowding of all terminal elevators during the past season with wheat, much of which showed signs of weevil infestation, the problem of developing a fumigant that could be depended upon became acute, and the ethylene oxide mixture was given a trial, the results of which were so gratifying that this mixture was used to fumigate several million bushels of wheat, likewise with excellent results.

Attempts were made to introduce the fumigant by applying it directly into the stream of wheat as the bins were being filled. In one instance the two gases were applied directly from cylinders, the materials being conducted through separate tubes leading into the top of the bin; in the other instance the ethylene oxide was mixed with "dry ice" (solid carbon dioxide) and the mixture poured into the grain as it entered the bin.

The use of dry ice has proved to be the most satisfactory method. In the preliminary tests 1 pound of ethylene oxide was used with 7 pounds of the dry ice and the dosage was figured on the basis of 2 pounds of ethylene oxide per 1,000 cubic feet of bin space. This dosage killed from 85 to 100 per cent of the weevils in concrete, steel, and wooden bins, some of which were closed whereas others were open at the top. The results of preliminary tests indicated the necessity for an increase in dosage, hence in subsequent fumigations 3 pounds of the ethylene oxide per 1,000 bushels of wheat was used. It was also decided to change the mixture of dry ice and ethylene oxide from a 7-to-1 ratio to a 10-to-1 ratio, so that the resulting product has a consistency resembling snow instead of being liquid.

Of the many fumigations conducted with the dry ice and ethylene oxide 10-to-1 mixture at the rate of 3 pounds of ethylene oxide or 33 pounds of the mixture per 1,000 bushels of grain, all but two have shown a 100 per cent kill, both in the planted test lots of insects and in the composite samples of wheat drawn from the bins. Of the two exceptions, one showed a 98.7 per cent kill and the other a 98.1 per cent kill.

The method of applying the ethylene oxide-dry ice mixture has been developed as a result of cooperative work between members of the Bureaus of Entomology, Chemistry and Soils, and Agricultural Economics, of the United States Department of Agriculture, the grain inspection department of the New York Produce Exchange, and the manufacturers of ethylene oxide.[6] Through the courtesy of Laurel Duval, chief grain inspector of the New York Produce Exchange, members of the Department of Agriculture were enabled to observe the results of several commercial fumigations conducted by him with the ethylene oxide and dry ice involving the treatment of several million bushels of wheat.

Briefly, the process consists of mixing together ethylene oxide, drawn as a liquid from steel cylinders, and dry ice in large pails and

[6] BACK, E. A., COTTON, R. T., YOUNG, H. D., and COX, J. H., THE USE OF THE ETHYLENE OXIDE-CARBON DIOXIDE MIXTURE FOR TREATING STORED GRAIN. 10 p., illus. 1930. (Multigraphed.)

introducing the mixture into the wheat as it is run into the bin. The mixture is carried down with the grain and is well distributed through it. It soon changes to a vapor that kills all weevil life.

As has been previously indicated, dry ice is really carbon dioxide in solid form. It is a white solid, easily crushed, and has a temperature of −110° F. On exposure to air it slowly changes from a solid to a vapor. For fumigation purposes a special type of dry ice is used that is not compressed so much as the ordinary type. It has the consistency of chalk and is very easily crushed. It is delivered in insulated boxes that prevent excessive evaporation. It is prepared for use by being broken into small pieces with a sledge and ice pick, and shoveled into garbage pails that hold about 70 pounds each. Since dry ice has a temperature of −110° F., it should not be handled with bare hands; if handled carelessly it is likely to blister the skin.

The ethylene oxide is poured over the crushed dry ice at the rate of 1 pound to 10 pounds of the dry ice. The mixture should be stirred a little so that all liquid will be taken up by the dry ice. To prevent unnecessary loss by evaporation, the materials should be mixed only as needed.

Once made, the mixture should be carried to the bin floor of the elevator and applied to the wheat stream without delay. It can be applied by shoveling it into the grain stream as it is about to enter the bin, or with a machine regulated to feed the mixture into the bin, by means of a worm drive. A dosage of 33 pounds of the mixture per 1,000 bushels of grain has been found to give excellent results. If the wheat is run into the bin at the rate of 12,000 bushels per hour, a 66-pound batch of the fumigant should be fed into the grain stream during every 10-minute period.

In order to counteract leakage at the bottom and top of a bin, the dosage for the first 1,000 bushels and the last 500 bushels is made proportionately greater than that for the rest of the bin. For example, in a 15,000-bushel bin, 66 pounds of the mixture is used for the first 1,000 bushels and 33 pounds of the mixture for the last 500 bushels. The dosage for the rest of the bin should be made slightly less than 33 pounds of the mixture per 1,000 bushels of grain in order to have an average of 33 pounds per 1,000 bushels for the entire bin.

Where the bin is open at the top, it is desirable to cap off the grain with a layer of the ethylene oxide-dry ice mixture in order to insure a perfect kill in the upper layer of grain.

When the fumigant is applied by shoveling the ethylene oxide-dry ice into the grain stream, the operator unavoidably inhales more or less of the gas. Inhaling small quantities of the gas is not harmful to the operator, but prolonged exposure to the fumes is likely to cause severe nausea, particularly in the presence of heavy grain dust. It is, therefore, well to assign two men to the task of shoveling, so that they can alternate in the application of each batch of the mixture. Should an employee become nauseated from too long an exposure to the fumes, the discomfort is only temporary, and no further ill effects need be feared.

The fumigation of wheat as above described does not appear to affect the milling or baking qualities of the wheat. No odors have been detected in the fumigated wheat samples. Germination tests

indicate that the fumigation of bulk wheat with the mixture does not materially affect its viability. However, it is unwise to fumigate small quantities of wheat intended for seed.

FUMIGANTS FOR VARIOUS STORED PRODUCTS

The work of developing new fumigants and of adapting them to commercial practice has been continued. Aside from the development of a successful method of fumigating wheat in terminal elevators, other experiments with ethylene oxide, alone and in combination with carbon dioxide, have been conducted, particularly in relation to insect control in such food commodities as nut meats, candies, dried beans, rice, breakfast cereals, flour, and cartoned goods and in such manufactured articles as upholstered furniture.

Ethylene oxide was used successfully in grocery stores, in hospital food-supply rooms, in fumigable storage bins in dried-fruit establishments, in work rooms, and candy establishments, and for treating cured tobacco. The Navy Department fumigated with excellent results over 10,000 pounds of sacked rice infested with the rice weevil (*Sitophilus oryzae* L.) in a quartermaster's depot of recent construction. In a house basement ethylene oxide proved effective against the webbing clothes moth (*Tineola biselliella* Hum.), the furniture carpet beetle (*Anthrenus vorax* Casey), the confused flour beetle (*Tribolium confusum* Duv.), and the rice weevil. In tight fumigating rooms no difficulty was experienced in killing tremendous numbers of the saw-toothed grain beetle (*Oryzaephilus surinamensis* L.), and the confused flour beetle in 1, 2, and 3 pound cartons containing such cereal products as farina, rolled oats, and corn flakes, or in killing the cadelle (*Tenebroides mauritanicus* L.) and the confused flour beetle in stacks of 96-pound sacks of wheat flour. No living specimens of the webbing clothes moth or the furniture carpet beetle could be found in heavily infested upholstered furniture treated in a modern fumigation vault.

Experiments indicate that nut meats of all sorts can be fumigated with ethylene oxide alone, or in combination with carbon dioxide, without taking on an odor or flavor detrimental to their immediate sale. Almonds, English walnuts, peanuts, pecans, and cashew nuts were fumigated and were pronounced by nut experts to be free from foreign odors and tastes.

Experiments indicated that when the temperature of the stocks and the fumigating room ranged from 75° to 78° F., rice, beans, dried fruits, and nut meats can be fumigated as described below.

RICE

Polished rice can be treated either in bulk or in sealed cartons. Rice does not adsorb much gas, and comparatively small quantities of the ethylene oxide are very effective against the insects that attack it. Bulk rice is more easily fumigated than package rice since more gas is required to penetrate the tightly sealed cartons. The dosages recommended are based on tests with adults and larvae of *Tribolium confusum*, larvae of the Indian meal moth (*Plodia interpunctella* Hbn.), and larvae of *Tenebroides mauritanicus*, as they are more resistant to the vapors of ethylene oxide than other rice-infesting

insects. The rice weevil, which is regarded by many as the worst insect pest of rice, is very susceptible to this gas, and may be killed in as short a time as 10 minutes. In atmospheric fumigation, bulk rice can be freed of insect life by the use of 1 pound of ethylene oxide per 1,000 cubic feet of space during an overnight fumigation. Under similar conditions rice in cartons requires a dosage of 2 pounds per 1,000 cubic feet in order to get a perfect kill. In vacuum fumigation ethylene oxide should be used in the proportion of 3 pounds per 1,000 cubic feet for 1 hour, or 2 pounds per 1,000 cubic feet for 2 hours, for treating bulk rice; and 3 pounds per 1,000 cubic feet for 2¼ hours, or 2 pounds for 3 hours, for rice in cartons. When used in combination with carbon dioxide, 2 pounds of ethylene oxide per 1,000 cubic feet for 1½ hours, or 1 pound per 1,000 cubic feet for three-fourths of an hour, is sufficient for the treatment of bulk rice, and 3 pounds per 1,000 cubic feet for three-fourths of an hour, or 2 pounds per 1,000 cubic feet for 1 hour, is required for the treatment of rice in cartons.

BEANS

Dried beans of all types may be fumigated either loose or in bags. For atmospheric fumigation 2 pounds of ethylene oxide per 1,000 cubic feet of space for an overnight exposure will kill all bean weevils present whether the beans are in bulk or in sacks. For vacuum fumigation 3 pounds of ethylene oxide alone per 1,000 cubic feet for 1 hour, or 2 pounds per 1,000 cubic feet for 2 hours, will give a perfect kill. In combination with carbon dioxide, experiments indicate that it is necessary to use 2 pounds of ethylene oxide per 1,000 cubic feet for one-half hour, or 1 pound per 1,000 cubic feet for 1 hour. Beans intended for seeding purposes should not be fumigated with ethylene oxide.

DRIED FRUIT

For the treatment of dried raisins, either in bulk or in cartons, 1 pound of ethylene oxide per 1,000 cubic feet of space will give satisfactory results in an overnight atmospheric fumigation, provided an air-tight vault is used. Double the quantity of fumigant should be used if the vault is not absolutely air-tight. In vacuum fumigation 2 pounds of ethylene oxide per 1,000 cubic feet of space for 1½ hours, or 3 pounds per 1,000 cubic feet for 1 hour, are necessary to give a perfect kill in both bulk and packaged raisins. In combination with carbon dioxide 2 pounds of ethylene oxide per 1,000 cubic feet for one-half hour, or 1 pound per 1,000 cubic feet for 1½ hours, is sufficient.

NUT MEATS

Experiments have shown that nut meats adsorb a much larger quantity of gas than most other foodstuffs and consequently require a correspondingly greater dose to insure a perfect kill. For the fumigation of raw, shelled peanuts or other nut meats, a dosage of 3 pounds of ethylene oxide per 1,000 cubic feet for an overnight exposure under atmospheric conditions is required. If used with carbon dioxide, only 2 pounds of ethylene oxide per 1,000 cubic feet is required. In vacuum fumigation 3 pounds of ethylene oxide per 1,000 cubic feet in combination with 28 pounds of carbon dioxide will

give a perfect kill in two hours. Ethylene oxide alone is not recommended for the fumigation of nut meats in vacuum owing to the excessive quantity that would be required to effect a kill.

CARBON DIOXIDE AS AN AID IN THE FUMIGATION OF HIGHLY ADSORPTIVE COMMODITIES

When the time element in fumigation work is of importance, as in some commercial establishments with a large daily output, vacuum fumigation is necessary. By this method of fumigation results may be obtained in from 1 to 2 hours that would require from 12 to 14 hours under atmospheric methods. But to get these quicker results, a correspondingly larger quantity of fumigant must be used. It was found, for example, that carbon disulphide will give a satisfactory kill in an atmospheric fumigation vault at a dosage of 2 pounds per 1,000 cubic feet of space for 24 hours, whereas it is customary for commercial fumigators to use as high as 40 pounds per 1,000 cubic feet in vacuum fumigation. In an empty fumigation vault, within certain limits, the time required to kill a certain insect is in direct proportion to the dosage. However, if the vault is filled with merchandise, the factors of adsorption and absorption present problems that are difficult to overcome, as these factors are not constant but vary with the type of commodity being fumigated, with the fumigant used, and with the temperature. Experiments conducted in small vacuum tanks of 8.7 and 21.76 liters capacity against *Tribolium confusum* gave interesting results at 72° F.

In an empty vacuum tank it required 2 ounces of chloropicrin per 100 cubic feet of space to give a 100 per cent kill of adults of *Tribolium confusum* in 2 hours. But when the tank was filled to capacity with raw peanuts it was impossible to kill 100 per cent in 2 hours even when a dose of 48 ounces per 100 cubic feet was used. In an endeavor to obtain a kill in 2 hours with a reasonable quantity of chloropicrin, tests were made with various mixtures of chloropicrin and carbon dioxide. After the customary 27 inches of vacuum was drawn the carbon dioxide was admitted to the tank, followed immediately by the chloropicrin. It was found that up to a certain point the more carbon dioxide used the smaller the quantity of chloropicrin required to give a kill. When used with carbon dioxide at the rate of 2.8 pounds per 100 cubic feet of space, 7 ounces of chloropicrin gave a 100 per cent kill of adult *Tribolium confusum* in 2 hours with the tank filled with raw peanuts. With 4.2 pounds of carbon dioxide per 100 cubic feet, 4 ounces of chloropicrin per 100 cubic feet gave a 100 per cent kill.

Experiments in an empty vacuum tank with 30-minute exposures at 72° F. indicated that the addition of carbon dioxide up to approximately the rate of 4.2 pounds per 100 cubic feet of space adds to the toxicity of chloropicrin in proportion to the quantity of carbon dioxide used. Higher percentages of carbon dioxide apparently do not increase the toxicity of chloropicrin beyond this point. To summarize the experiments briefly, a 100 per cent kill of *Tribolium confusum* was obtained in 30 minutes with 6.6 ounces of chloropicrin per 100 cubic feet when used alone; with 4.6 ounces of chloropicrin when used with 1.4 pounds of carbon dioxide per 100 cubic feet; with 2 ounces of chloropicrin when used with 2.8 pounds of carbon dioxide per 100 cubic feet; and with 1.28 ounces of chloropicrin when used with 4.2 or more pounds of carbon dioxide per 100 cubic feet of space.

Experiments with ethylene oxide indicate that this gas is not adsorbed or absorbed by nut meats to such an extent as is chloropicrin. In an empty vacuum tank ethylene oxide used alone at the rate of 3.2 ounces per 100 cubic feet of space gave a 100 per cent kill of adult *Tribolium confusum* in 2 hours at 72° F. In the tank filled with raw peanuts, it required 11.2 ounces of ethylene oxide per 100 cubic feet to give a 100 per cent kill in 2 hours. With the addition of carbon dioxide at the rate of 2.8 pounds per 100 cubic feet, 4 ounces of ethylene oxide gave a 100 per cent kill in 2 hours in the tank filled with peanuts. Larger quantities of carbon dioxide did not materially increase the toxicity of ethylene oxide.

Additional experiments with other highly adsorptive materials indicate that carbon dioxide can be used to advantage with other gases in the fumigation of many materials that it has hitherto been difficult or impractical to fumigate successfully.

HOUSEHOLD INSECTS

The work on household pests has been of a very general nature during the past year. Numerous experiments have been conducted to determine as far as possible from laboratory work the value of a number of so-called moth-proofing solutions. While no solution at present available to the public has proved itself capable of permanently or completely moth-proofing any fabric, laboratory results indicate that the better cinchona alkaloid solutions and those containing fluorine compounds are capable of imparting a moth resistance that is of practical value. To be of value they must be applied in such a manner that the fabric is thoroughly wet by them. The outstanding feature of the work with moth-proofing solutions is the cooperative work conducted with the Bureau of Chemistry and Soils in developing a solution that can be offered the public under a public-service patent. This has led to tests of different strengths of a rotenone dissovled in acetone which gave such gratifying results that a public-service patent was applied for in February, 1930.

Rotenone is one of the insecticidal constituents of Derris root, cubé root, and other tropical fish-poisoning plants. It is a white crystalline material of the formula $C_{23}H_{22}O_6$, with a melting point of 163° F. It is quite insoluble in water, is very slightly soluble in petroleum oils, slightly soluble in alcohol and ether, and readily soluble in choroform, ethylene dichloride, and other chlorinated hydrocarbons.

Cloths treated with solutions containing 1 per cent and 2 per cent of rotenone dissolved in acetone were thoroughly protected against the ravages of the webbing clothes moth (*Tineola biselliella* Hum.), the furniture carpet beetle (*Anthrenus vorax* Casey), and the black carpet beetle (*Attagenus piceus* Oliv.), when they were confined in Petri dishes both with and without untreated cloths. Even 0.05 per cent solutions of rotenone in acetone gave excellent protection. It is hoped that this solution can be developed sufficiently to become available to the householder.

BEAN WEEVILS

The hearty support given the bureau in its investigation of bean and cowpea weevils in Merced, Stanislaus, and San Joaquin Coun-

ties, Calif., has continued during the year. The scope of the work has not changed. The nature of the investigation is such that it will be several years before a satisfactory conclusion can be reached as to the exact value of the present campaign in reducing the weevil population on the farms by a concerted attack upon storage conditions. It has been estimated by California officials that an infestation of more than 50 per cent has been reduced during the past two years to one of less than 4 per cent in many sections. It is admitted that the damage caused by weevils no longer assumes the major proportions of two years ago. This generally acknowledged practical result has been made possible only by the whole-hearted support given the bureau by California city, county, and State organizations.

FLOUR-MILL INSECTS

The flour-mill-insect project has been continued during the year, in part, in cooperation with the Kansas State Agricultural College. Preliminary investigation has indicated that air currents on ships transporting flour are capable of carrying flour-infesting insects from one part of a ship to another. This explains the importance of keeping all compartments of ships as free as possible from insects affecting flour lest infestation take place while a consignment is en route. Further investigation of railroad cars indicates the possibility that they may become a source of insect infestation through flour shipped in them from the mill to the port. It has been demonstrated that the heating of wheat sufficiently to kill insects will not injure the milling or baking qualities of flour made from the wheat. Continued study of the flour-mill-insect problem indicates that wheat brought into the mill for grinding brings with it insects that tend to offset the value of mill fumigations. It is believed that the heat treating of wheat just as it enters the mill will aid in eliminating this source of infestation of mills, and machinery satisfactory for such use of high temperatures is being installed and will be made a subject of observation. The use of mill sprays, and of different fumigants both in the mill at large and in the warehouse and fumigating vault, is still the object of continued research.

DRIED-FRUIT INSECTS

During the year the activities of this investigation were extended to the date industry in the Coachella Valley. Traps were placed on two ranches there, and the insects captured, mostly nitidulid beetles, were the same species as those which infest figs in the San Joaquin Valley. The Deglet Noor Date-Growers' Association decided to use ethylene oxide as a fumigant for their product as a result of experiments conducted.

The fig moth (*Ephestia cautella* Walk.) was present in large numbers in new-crop raisins, and the migrant larvae were very numerous, beginning in October, 1929. The infestation was heavier than in 1928, when the insect first appeared as an important pest of new-crop raisins. Growers and packers for the first time were quite generally concerned about infestation in their raisins, but the proposed systematic fumigations of all raisins, either on the ranches or upon delivery at packing plants, were found to be unnecessary.

The value of dusting sulphur as a possible repellent against the dried-fruit beetle (*Carpophilus dimidiatus* Fab.) and its allies was thoroughly tested on four ranches without beneficial results. Trapping of the beetles was continued in fig orchards, as during last year, to determine their relative abundance. Apparently because of the cold winter of 1928–29, the beetle population in fig orchards was low, fulfilling the indications of the results of trapping in the spring of 1929. The condition of the crop of Adriatic figs was much better than in 1927 and 1928, and there can be little question that this was a direct result of the decreased nitidulid-beetle population. Trapping in the spring of 1930 indicated that the beetles were considerably more numerous than in the spring of 1929.

It is gratifying to report continued progress in the installation by private firms of equipment making satisfactory fumigations of stocks possible. The bureau's efforts during the past three years have resulted in great improvement so far as infestation of figs by storage pests in packing houses is concerned. The use of ethylene oxide as a fumigant in the dried-fruit industry has increased.

An important phase of the investigation of dried-fruit insects has been the biological studies of the fig moth (*Ephestia cautella*), the dried-fruit beetles *Carpophilus hemipterus* L. and *C. dimidiatus* Fab., the moth *Aphomia gularis* Zell., and the hymenopterous parasite *Habrobracon juglandis* Ashm. The chocolate moth (*Ephestia elutella* Hbn.) and the moth *Aphomia gularis* were noted for the first time as pests of prunes. An ant, *Formica fusca argentata* Whir., was observed preying upon fig-moth larvae near raisin stacks in the Fresno district.

Experiments with oil-treated raisins were conducted, but in no case did the results promise immunity of oiled fruit from insect attack, although it is probable that insect infestation of packed stock can be retarded by the oil treatment. The efficacy of a triple-sealed prune package was demonstrated by the exposure to infestation of a series of cartons, both with and without the outside wrapper or label.

Examinations of empty railway cars prior to loading with dried fruits were begun in December, 1929, and continued at intervals in order to secure information about the insects found in such cars. Empty sweat boxes, which sooner or later are returned to ranches from the packing house, were likewise examined at intervals to determine the extent to which insects in them might find their way back to ranches and contribute to the building up of infestation in new-crop fruit.

During the year five papers were prepared giving results of investigational work, 481 visitors were received at the laboratory at Fresno, 147 ranch visits were made, 203 packing-house calls were made, and about 15,000 passenger miles were traveled.

INSECTS AFFECTING MAN AND ANIMALS

This work has been conducted under the direction of F. C. Bishopp.

SCREW-WORM FLY AND OTHER BLOWFLIES

The utilization of flytraps for the control, under range conditions, of the screw worm and fleece worm is being further studied in a typical stock-range area in Texas. By locating a series of traps in carefully selected locations representing the various types of grazing

areas in that section, basic information is being obtained which should serve as an index to trap location and thus greatly increase the efficacy of the traps in catching flies. A wide variation in the number of flies caught in the different environments clearly shows the need of such investigations. In these specially located traps the number and sex of all injurious species are being determined and correlation studies made with reference to evaporation, as determined by atmometer readings, and to various other environmental factors. Fly trapping is being very widely employed by ranchmen, and the failure of such control efforts to reduce materially the number of screw worms and fleece worms on livestock further emphasizes the need of these fundamental studies.

Tests of a number of different types of small flytraps have been made in comparison with the conical trap developed by the Bureau of Entomology, and none of these has been found so effective as the conical trap. In addition, a new type of trap has been designed and tested. This is a large trap made to utilize the whole carcass of a cow as bait, to prevent the escape of flies which breed in it, and to encourage the breeding of parasites of the immature stages of the flies. While the true value of these large traps has not yet been fully established, their value with respect to convenience in servicing and as a means of disposing of carcasses is evident, and several ranchmen have installed them. Tests of baits of different kinds and quantities used under standard conical traps have been continued, but no satisfactory substitute for meat has been found.

The native parasites and predators of the blowflies have been given considerable attention. The life history, seasonal history, and host-species preference of the chalcid parasite *Brachymeria fonscolombei* Dufour have been studied. This species is given special attention because of its habit of attacking the flies in their larval stage. It has been found, however, to prefer the larvae of the sarcophagid flies to those of the more important economic species. Status studies still indicate that *B. fonscolombei*, the local larval parasite, may be of considerable economic value in the control of screw-worm flies in small carcasses. In 10 jars in one series an average parasitism of 96 per cent has been obtained, and in six series at one time an average of 88 per cent was shown. Releases of approximately 8,000 adult parasites in a certain pasture over a period of two months indicated that the percentage of parasitism increased much more in this pasture than that of the parasitism in pastures where no releases were made. *Mormoniella abnormis* Boh., the common pupal parasite at Uvalde, Tex., has not been shown to have a very considerable economic value. Three, and possibly four, other parasites have been reared from fly pupae but have nat as yet been studied. It has been determined that some 15 to 20 insect predators have some value in the destruction of the several stages of flies that breed in flesh, and there are indications that some of these have considerable economic value.

CATTLE GRUBS

Investigations of cattle grubs have been continued along the lines indicated in the last report. Certain phases of the work have been carried on cooperatively with the Bureau of Animal Industry in the localities where area control is being tested. An inquiry into the

present distribution of the northern cattle grub shows this most destructive species to be present in Idaho, Washington, Utah, Minnesota, and West Virginia, States in which it was not previously known to occur. This species has also become more generally established in several of the Northern States, where it was previously found only in scattered localities.

Investigations of the areas of grub scarcity have been centered in the Red River Valley of Minnesota. The evidence collected there points to the operation of several controlling factors, particularly the heavy soil, the practically level terrain, and the seasonal distribution of rainfall. As the work has been done during two unusually dry years, however, the findings differ from the normal. In fact, cattle-grub infestations were found in the Red River Valley during the spring of 1930, a condition unheard of previously, but supporting the idea that rainfall, drainage, and soil factors are responsible for the normal absence of grubs in this section. A preliminary survey was made of the districts in Florida where cattle grubs do not occur. The territory of normal occurrence of the cattle grub was fairly well defined, but further studies of the factors responsible for this condition are needed.

Investigations of insecticides for use in destroying the grubs in the backs of the cattle were continued. Special attention has been given to the quantity of tobacco powder, nicotine dusts, and Derris required to give effective control. This work indicates that the use of 2 or more ounces of Derris powder per animal is necessary when the entire back of the animal is to be treated. In using nicotine-sulphate dust, better kills resulted when rather heavy applications of the dust were made to each grub than when a general but lighter application was made to the entire back of the infested animal. Tests were conducted to determine the toxicity incident to treating cattle with known quantities of nicotine preparations. In tests of previous years it had been proved that nicotine sulphate and free nicotine in dust carriers, as well as natural tobacco powders, are efficient larvicides for Hypoderma in cattle. No toxic effect on the host has been apparent from the quantities applied. The question arose as to whether a general application all over the back of an animal, when the animal is heavily infested, would result in toxicity to the host. The Bureau of Entomology and the Bureau of Animal Industry cooperatively conducted a series of tests to get some information on this point. In preliminary tests with a few animals it was found that free nicotine in inert dust, applied in the amount of 3 ounces of 2 per cent, did result in slight toxosis. Similar tests with nicotine sulphate in the same quantities revealed no such reaction in the host. After the preliminary tests were completed, more extensive applications were made with nicotine sulphate in inert dust. No poisoning of the host resulted.

SHEEP SCAB MITE AND GOAT LICE

Investigations of these important pests of sheep and goats were continued in cooperation with the Texas Experiment Station at Sonora, Tex., and at the Dallas, Tex., laboratory of the bureau. The ability of sheep scab mites to persist for months on a sheep without any external evidence of infestation was demonstrated in experimental animals.

Tests of insecticides for control of goat lice were continued, and certain fine grades of sulphur were found to effect complete destruction of all species of goat lice when applied thoroughly as a dip. These sulphur dips are not injurious to the mohair and are nonpoisonous to the goats. Although a single dipping gave 100 per cent control on experimental animals, in tests under range conditions a few lice were found to survive, thus making a second dipping necessary for eradication. An interval of 11 days between the two dippings is indicated as most effective.

EYE GNATS

Investigations of the biology and methods of control of the eye gnats (*Hippelates* spp.), initiated last year, were continued. While the exact conditions under which these gnats breed in nature has not yet been determined, it has been proved that they will breed freely in several different materials, such as excrement of man and animals, decaying meat, and fermenting vegetable matter. By the use of large numbers of field-recovery cages it has been shown that the gnats are breeding in the soil over wide areas. These tests indicate that the type of soil, the cultural methods employed, and the cover crops turned under have important bearings on the breeding of the pest.

Trapping of the gnats as a control procedure and to obtain accurate information on the seasonal occurrence and local distribution of the insects has received much attention. A simple and effective trap has been developed. Liver and urea have been found to make a very attractive bait. The use of traps decidedly reduces annoyance from the gnats, and since a large percentage of the gnats caught are gravid females it appears likely that some degree of control may be effected by systematic trapping.

MOSQUITOES

Studies of the food habits and natural ecology of the larva of *Anopheles quadrimaculatus* Say were continued at Mound, La., this year, being the third year of comparative observations to determine the environmental factors affecting the abundance of this species. Monthly records were made in a series of breeding and nonbreeding places to show the abundance of larvae, the quantity of protective material present, counts of the different genera of microscopic aquatic organisms per unit volume of water, and the hydrogen-ion concentration of the water. Parallel dissections of larvae were made to identify the food ingested under the recorded conditions, and correlative studies are being made of the accumulated data.

Laboratory tests with different species of legumes have been started to determine whether the adult Anopheles are able to feed and subsist on the nectar or juices of such plants. These were undertaken in view of the theory that malaria parasites are destroyed by the action of the chemical coumarin present in leguminous plants and that malaria is therefore absent in areas where legumes are extensively grown. The results so far have not shown the ability of *Anopheles quadrimaculatus* to feed on such plants.

Records of the comparative density of mosquito populations, which have been kept over a period of 11 years, showed a very large increase in the abundance of Anopheles during 1928 and 1929 over the previous four years, but the abundance was comparable to that during the four years from 1920 to 1923. This return to a more normal output of malaria mosquitoes from the breeding areas was apparently reflected in a marked increase of malaria among the tenant families during 1929.

Important information on the life history and habits of the pest mosquito *Mansonia perturbans* Walker has been derived from studies conducted at Zellwood, Fla. Contrary to the general belief, this mosquito appears to have several broods annually in that section. In Florida the water plant Pontederia appears to constitute the only species to which the larvae of this mosquito will attach and on which they will develop. This explains in part the restrictions in breeding areas of this mosquito, which have been noted previously.

BEE CULTURE

The work of the bee-culture laboratory has continued under the direction of James I. Hambleton, with headquarters at Somerset, Md.

BEHAVIOR OF BEES

In the work on artificial insemination of queen bees by the Watson method a glass pipette fitted with a glass plunger has been successfully used. Twenty-five to thirty per cent of the queens operated upon thus far with the original or the modified plunger have shown some degree of insemination. In previous years only virgins reared from naturally mated queens were used, but this year virgins from the F_1 generation of artificially inseminated queen bees are being tried as well. By modifying the California queen cage, as many of the treated queens as desired or convenient are now being kept in one hive, thus cutting down the number of bees and frames of brood required to test whether or not the queens are successfully inseminated. Drones of desired stock are being marked on emergence in an endeavor to determine the proper relative age at which to use drones. By buying mature drones from the South the season during which artificial insemination may be conducted is made from four to six weeks longer.

Studies of the biometric measurements of the honeybee have been continued. Physical characteristics other than length of tongue are being studied in an effort to establish a definite basis for distinguishing between the various races and strains of the honeybee.

During the year one article on the races of the honeybee was published by the department, and two articles on this topic were published outside the department. One article dealing with certain phases of the work on artificial insemination was also published outside the department.

The investigation on the relative stimulative efficiency of various regions of ultra-violet for the honeybee has been finished, and the results reported upon orally before the American Society of Zoologists at Des Moines, Iowa. A written report has also been prepared for publication.

Data obtained during the year on the variation in the flight of honeybees to an artificial source of nectar are being studied in conjunction with weather factors. Because of the necessity for making further improvements on the flight-recording instruments, apparatus to secure similar data at the field stations has not been installed.

Work has begun on the making of a motion picture depicting the behavior of bees in such activities as the collection of nectar, pollen, and propolis and in the building of comb.

In cooperation with the division of forage crops of the Bureau of Plant Industry, experiments have begun at Holgate, Ohio, in a study of the behavior of honeybees in the pollination of red clover. In these experiments honeybees will be confined to plots of red clover, and in other cases attempts will be made to determine the importance of other nectar-secreting plants in attracting the bees from the red clover. It is also planned to stimulate the bees artificially to work on red clover.

PHYSIOLOGY OF BEES

The investigation of the physiological effects of ultra-violet rays on the brood and adults of worker bees and on adult queen bees has continued. The results so far indicate that ultra-violet rays even in minimum quantities are detrimental to all stages of the brood, and thus far it has not been possible to give a beneficial exposure. In conjunction with the testing of queens treated with ultra-violet rays an experimental apiary has been established at New Windsor, Md., where the fecundity and the longevity of queens can be studied under commercial conditions.

An effort is being made to prepare a stain for permanently marking large numbers of adult bees. A method of marking would be a great asset in studying the flight of bees from individual colonies, and other problems of behavior and physiology.

Work on the longevity of package bees and queens is still in progress.

BEEKEEPING REGIONS IN THE UNITED STATES

The study dealing with the cost of honey production and apiary management in the Intermountain States, undertaken in cooperation with the Bureau of Agricultural Economics and State beekeeping specialists, has been continued. A multigraphed preliminary report showing the progress of the first year's work has been published. Unless the honey crop in the Intermountain States is decidedly abnormal the present season will probably conclude the work in that region which has been carried on during the past three years. A similar study has been begun in the white-clover belt of the Great Lakes area. Cooperators are keeping records in New York, Ohio, Indiana, Michigan, Wisconsin, and Minnesota. The work in this area will also be conducted cooperatively with the Bureau of Agricultural Economics and the State beekeeping specialists. Judging from the correspondence, much interest is being manifested in these studies. Beekeepers from other parts of the United States have asked that similar studies be inaugurated in their sections of the country. Beekeeping organizations in some of the foreign countries have also shown considerable interest in the results that are being obtained.

Phenological studies on the principal nectar-producing plants continue. This work is being conducted largely through correspondence and consequently progress is slow.

The bee-culture laboratory has been collecting for the Bureau of Chemistry and Soils samples of the principal honeys produced in the United States. Various investigations on honey are in progress in that bureau. In addition to the fine types of commercial honeys, samples are being collected of the principal so-called undesirable types of honey which are produced in commercial quantities, but which do not have a ready sale because they are off-flavor or off-color. An effort will be made to improve the qualities of these honeys and to use them in products where the remaining undesirable characteristics will not be objectionable.

DEMONSTRATIONS IN BEEKEEPING

As has been the custom during the past few years, it has been necessary, because of lack of funds and personnel, to refuse many invitations to participate in meetings of beekeepers' organizations. Several observation hives have been prepared and lent for school and laboratory use, and a number of short manuscripts, many photographs, and other educational material on bees have been furnished to schools, the press, and feature writers.

A catalogue has been completed listing all the beekeeping literature in the Department of Agriculture and the Library of Congress. This work has been done in cooperation with the librarians of the Department of Agriculture and of the Bureau of Entomology.

DISEASES OF BEES

During the year 780 samples of brood and adult bees were submitted for diagnoses. The number of samples of treated comb, which necessitate cultural tests to determine sterility, has increased considerably over similar work in previous years. Seventy-six queen bees were imported from foreign countries for various scientific institutions and queen breeders.

The majority of samples submitted by honey producers who have tried the gas method for disinfecting American foul-brood combs showed lack of sterility. The reasons for failure of this method when employed outside the laboratory seem to be that the tanks and fumigating rooms used by beekeepers have not contained sufficient formaldehyde and that the period of exposure has been too short. The gas method for sterilizing brood combs infected with *Bacillus larvae* is not promising.

A report of laboratory studies dealing with the fumigation of American foul-brood combs in glass jars, paraffined hive bodies, and large tanks is being prepared for publication.

In connection with the work of fumigation, it has been the practice hitherto to allow treated combs to dry thoroughly before culturing them, in order to remove as much of the formaldehyde as possible; but it has been discovered that even though the odor of formaldehyde may not be detected in treated scales they often retain sufficient formaldehyde to inhibit or entirely prevent the growth of the organism in culture. This being the case, all treated scales are now thoroughly washed before culturing. The time during which

cultures are kept under observation in the incubator has also been lengthened, as it is found that the incubation period varies much more than was hitherto supposed. This is particularly true of the organism when it is obtained from treated combs. A report covering this work was published in one of the domestic bee journals.

INTERMOUNTAIN LABORATORY

The work of the intermountain field laboratory is being done under a cooperative agreement with the University of Wyoming. Efforts to determine the minimum number of spores per cubic centimeter necessary to cause American foul brood in a colony have been continued at Laramie, Wyo. It was found that an error had been made in calculating the number of spores used in previous experiments, and that the figures obtained were only one one-hundredth as large as they should be. A modification of the method devised by Breed for counting bacteria in milk was used to count the spores in a suspension of sugar sirup. By this method the results checked with those previously obtained by means of the Helber bacteria-counting cell. It was found that a minimum number of 50,000 spores per cubic centimeter, or a total of 50,000,000 spores per liter of sugar sirup, fed to a healthy colony would produce disease, whereas to date a smaller number has failed to produce disease. In conjunction with these experiments, individual larvae are being fed a definite number of spores to determine the actual minimum lethal dose.

In the study of the spread of American foul brood in commercial apiaries, the method for detecting a weak vegetative growth of *Bacillus larvae* has been improved. A medium which is a combination of the yeast egg-yolk suspension and Lochhead's carrot-extract medium gave a delicate test for slight quantities of *B. larvae*. A very characteristic positive nitrate-reduction reaction resulted from using the naphthylamine and sulphuric acid test. This method was used also in detecting spores of *B. larvae* removed from commercial honeys. As a check on the number of spores found in commercial honeys, field feeding tests will be conducted with part of the identical sample used in making laboratory cultures.

In attempting to determine the effect of commercial honeys in the spread of American foul brood it was found that less than a certain minimum number of spores per cubic centimeter growth in culture could not be obtained even after 30 days' incubation.

The third year of studies dealing with the flight range of the honeybee was concluded in the fall of 1929. During the course of the experiment it was found that when necessity demanded, bees flew at least 8½ miles to a source of nectar and returned. A distance of 2 miles from the source of nectar had but little effect on the average gain in weight made by colonies. Beyond a 2-mile point the gain decreased with the increase in distance. During 1928, which was a good honey year, all colonies located on a line extending for 7 miles into the Bad Lands made slight gains in weight, those beyond losing weight, whereas in 1929 colonies located 5 miles and more from the source of nectar lost in weight. In 1929 a loss in weight was recorded for colonies located 6 miles and more from the source of nectar. During the three years, colonies located some distance from the source of nectar made greater gains than colonies

located within the source of nectar. During the summer of 1930 studies are being conducted near Alamosa, Colo., in the San Luis Valley, in an effort to determine the distribution of bees within the source of nectar. A paper entitled "The Flight Range of the Honeybee," giving the results of the three seasons' work, has been prepared.

Various methods of wintering in the Intermountain States are being studied in which experimental colonies and colonies belonging to commercial honey producers at Fromberg, Mont., Fort Collins, Colo., and Lander and Laramie, Wyo., are being used. Different methods of packing, the contrasts between cellar and outdoor wintering, the use of upward ventilation, and other factors are being given attention. Colonies of Italian and Caucasian bees are being used.

SOUTHERN STATES LABORATORY

A study of the various types and sizes of packages used by the producers of package bees has reached the point where it seems quite possible that three or four standard cages can be recommended to take care of all the needs of the package-bee shipping industry. Two of these packages are designed for the shipment of nuclei or frame packages, and the other two for the 2–pound or 3–pound combless package. After the shippers have had an opportunity to study the types of cages which appear best, both from the standpoint of successful shipping and from that of economical construction, efforts will be made to give all shippers of package bees an opporunity to adopt these cages. Not only are the sizes and types of cages being studied, but the position of the queen bee in the package, the kind and quantity of food, the method of crating, the amount of ventilation, and other factors are being given careful consideration. Trial shipments of package bees in containers of different styles have been made, to learn the effect of actual travel conditions upon package bees.

In conjunction with the study of the plants producing nectar and pollen in the Southern States, begun last year, particular attention is being given to the blooming period of plants, their abundance and distribution, and their periods of nectar secretion. An attempt is also being made to determine whether the variation in hydrogen-ion concentration of the soils is correlated with the secretion of nectar from certain plants. Over 200 specimens of southern plants upon which honeybees have been observed gathering pollen or nectar, or both, have been collected by the Southern States Bee Culture Field Laboratory. Both the department of botany of the University of Louisiana and the Bureau of Plant Industry have given assistance in the identification of these plants. Colonies of bees have been located within range of areas of *Trifolium repens*, *Senecio glabellus*, and *Sabal* sp. (palmetto) to determine the quantity of nectar secreted and the effect of weather factors upon these plants during the period of nectar secretion. Colonies of bees have also been placed within a large wooded swampy area to determine the value of miscellaneous plants growing within the swamps.

A study is being made of the number of egg tubules comprising the ovaries of queen bees, and the relation between the number of egg tubules and the egg-laying capacity of queens. Queen bees already examined from various southern breeders show that the number of

egg tubules ranges from 90 to 175. Queens will be reared under different experimental conditions to determine the influence of certain environmental factors upon the number of egg tubules. In close relation to this, bees from various southern breeders are being collected to determine the extent of variation in strains sold by different breeders, and to determine if possible what headway toward the improvement of stock has been made by breeders who are making a conscientious effort to improve their bees.

Work on hand-mating of queen bees without the use of instruments has been conducted during the past season, and the results obtained so far indicate that the method has considerable promise, for a partial degree of insemination can be effected in all cases. The Southern States laboratory possesses a few hand-mated queens that to all appearances are equal to those mated in nature. For the time being efforts will be concentrated upon the technic of insemination. For this reason many queens are dissected shortly after being inseminated and the results checked with the spermatheca of naturally mated queens.

TAXONOMY AND INTERRELATIONS OF INSECTS

As at present organized, this division includes several different units, all representing fundamental studies of insects and insect relations. The taxonomic unit covers technical or basic work with insects, including their scientific study from the standpoint of identification and classification, conducted in cooperation with the United States National Museum. In addition to such strictly taxonomic work, this division includes the insect-pest survey work of the bureau, which has been maintained for several years, and also studies in insect anatomy, morphology, and physiology, and a special investigation which has been going on for some years under the title of research in bioclimatics, dealing with insect occurrence and biology as influenced by climatic conditions. The determinations which are made by the bureau in the field of insect diseases also are brought under this division, which as a whole has been under the personal supervision of the chief of bureau.

TAXONOMIC UNIT

The investigations in taxonomy have been conducted under the direction of Harold Morrison. The summary of determinations made, as given later, indicates that there has been an increase in the demand for service from this unit and that this increase has been met with some success.

While definite progress in the way of organizing the collections for proper study and identification purposes was made in all groups during the year, there was the greatest development in the Coleoptera in this respect since the addition of a specialist to work particularly on the weevils permitted the dividing up of the work on the Coleoptera and the assigning of important families and groups to individual specialists. A great deal of work of this sort is still to be done before the collections attain a condition which will permit their really effective utilization for identificaton work.

The needs of the bureau for additional specialists in insect classification remain serious. The most important needs at the present

time, as indicated in the requests for increases covering work in various groups, are for specialists and accessory assistants for studies on cutworms, for studies on scale insects, for studies on May beetles and click beetles, for studies on sawflies and parasitic wasps, and for studies on parasitic flies. Increases have been granted by Congress which will permit the employment of a specialist to work on the true bugs and a specialist to work on mosquitoes and other blood-sucking flies. Steps are now being taken to employ these specialists.

A check of our records indicates that 13,750 identifications have been made during the fiscal year. The service so supplied has benefited many branches of the Department of Agriculture, the National Museum, the Smithsonian Institution, the Public Health Service, and other Government departments or branches, State experiment station workers, college and university workers, and many individuals in the United States and elsewhere interested in entomology. The tabulation of the identifications made, by insect orders, follows:

Order	Identifications	Order	Identifications
Coleoptera	3,594	Ectoparasites and mites	524
Lepidoptera	2,983	Hemiptera	436
Diptera	2,034	Coccidae	1,490
Hymenoptera	2,127		
Orthoptera and Neuroptera	562	Total	13,750

This total is the largest that has been reported for identification work by the taxonomic group since the beginning of record keeping, and it appears, so far as the trends represented have been studied, to represent not only an absolute increase but also an increase in average difficulty of the work, since the reduction—remarked on in last year's report—in requests from the Plant Quarantine and Control Administration for the identification of relatively common, well-known species is again apparent in the work performed during the fiscal year 1930.

The outstanding development in the year's taxonomic work undoubtedly is to be found in the purchase of the Barnes collection of Lepidoptera at a cost of $50,000. This item was carried in the second deficiency bill and was approved by Congress just after the close of the fiscal year. As a result of this purchase more than 450,000 specimens, including many types and a practically complete representation of the species of Lepidoptera of the United States, will be added to the collections available to specialists for study purposes. Also, the purchase enables the department to acquire an extensive special library on the classification of Lepidoptera, including many rare technical papers and a card catalogue said to contain reference cards giving citations for every time a United States species of Lepidoptera has been mentioned in scientific literature.

The progress made in the preparation of monographic and other critical studies in the various projects has been, briefly, as follows:

COLEOPTERA

The arrangement whereby F. Ohaus, of Mainz, Germany, has identified large numbers of beetles belonging to the scarabaeid subfamily Rutelinae for the benefit of the bureau has been continued. As a result of the work of Doctor Ohaus and the bureau specialist on this group the collection in this subfamily, which includes the

Japanese beetle and many other pests of great economic importance, is in such condition that it can be used most efficiently for identification work. As it stands to-day it is probably the second or third best collection of these insects in the world.

In July, 1929, a specialist was added to the staff to care for certain groups, particularly the weevils, but owing to the fact that he remains on a half-time basis for the present, in order to complete certain work which he had undertaken for the Smithsonian Institution, there has been but little opportunity for him to undertake serious investigational work. Several papers describing new species of Cerambycidae and Buprestidae from various parts of the world have been completed and offered for publication. Work on coleopterous larvae has been very actively continued, two papers having been published and several others advanced, including an extended paper on the classification of the larvae of the whole order.

LEPIDOPTERA

Work has been continued on the Tortricidae, and comparative studies undertaken on some secondary sexual characters of certain families of microlepidoptera. Study on the American Phycitinae has been further advanced, but in all probability it will be several years before the monographic work on it has been completed. In addition, to meet certain problems which developed during the year, special studies on certain genera of Noctuidae have been undertaken.

The work of adding the Brooklyn Museum collection of Lepidoptera, transferred from that institution to the United States National Museum last year, has been completed, and in this connection many thousands of specimens have been properly classified and arranged. In addition to this, work has been conducted on Geometridae and neotropical species of certain other families and subfamilies. Preparation of a report on Lepidoptera in connection with the Biological Survey of Porto Rico, which was organized under the auspices of the American Museum of Natural History, has been in progress for some time.

DIPTERA

The bureau's specialist on fly larvae has continued to serve in making identifications of mosquitoes and other blood-sucking flies, a task in addition to his regular duties which he has carried for more than a year and a half. In the course of his work he has been able to give identifications or other assistance to a considerable number of entomologists, but the extra duties which he has assumed have prevented the completion of investigational work which he has had in progress.

HYMENOPTERA

In addition to the regular identification work, study on the genus Trichogramma has been continued. The study of this genus has developed certain complexities which have retarded completion of a paper. Several papers dealing with various groups of species of Ichneumonidae have been completed and published during the year. Preliminary studies on the classification of different genera of bees and wasps have been made in order to facilitate determination work on them.

ORTHOPTERA AND NEUROPTERA

By request, the bureau's specialist on these orders has during this fiscal year undertaken a study of the Copeognatha (book lice, etc.) of the world in order that he may supply to the Plant Quarantine and Control Administration identifications for the material which they collect rather frequently in the course of their port-inspection work. He is successfully familiarizing himself with the classification of this order of insects and with the species included in it so that he is now supplying desired information on these insects to the Plant Quarantine and Control Administration and others.

ECTOPARASITES AND MITES

Papers describing new species of Mallophaga and mites have been prepared during the year and revisional studies on the feather mites continued. Field studies on the biology of the chiggers have also been continued.

COCCIDAE

The situation in the Coccidae remains much as it was in the previous fiscal year. Developmental work which will permit the production of monographic or other research papers has been kept up, so that when there is an opportunity it should be possible to prepare and publish some very useful papers on the classification of scale insects. There is no possibility of this under present conditions, since general administrative work takes up a large part of the time of the specialist on Coccidae, and in consequence many demands for identifications and other assistance either have not been met at all or have been met unsatisfactorily.

The outstanding development in connection with the bureau's coccid work for the past year undoubtedly is the acquisition by purchase of the C. F. Brain collection of South African Coccidae, including types or authentically identified examples of almost all of the species which Doctor Brain described in the course of his work in South Africa on this family. This most important and useful addition to the collection will permit the accurate identification of specimens from South Africa now received through the Plant Quarantine and Control Administration and other sources.

It is anticipated that the further increase in staff which will be made during the coming year will result in improved effectiveness in the handling of identification and other service work of the taxonomic unit and greater benefit to all those needing assistance, but there must be a marked further increase in the staff and additional reorganization of the work before it will be possible to perform the duties assigned to the unit in a wholly satisfactory fashion.

INSECT-PEST SURVEY

The insect-pest survey, as in the past, has been under the direction of J. A. Hyslop.

The purpose of the insect-pest survey is to maintain and make available a permanent record of insect abundance and damage and to make such studies and research of those records as may lead to determination of the basic factors of insect distribution and abun-

dance. This survey is carried out in cooperation with all of the States having organized entomological activities and by informal arrangements includes also Canada, Cuba, Porto Rico, Haiti, Mexico, and the Hawaiian Islands. The total number of regular reporters on insect conditions is now 87.

A monthly record of the insect conditions as reported to the survey is issued, some nine volumes of which have now been completed. These records are distributed to several offices of the Bureau of Entomology, to the field stations of the bureau and also of the Plant Quarantine and Control Administration, and to State institutions and all collaborating agencies, domestic and foreign.

An index is being maintained of all the records of both North American and foreign insect pests, and this catalogue is being cross indexed under host-plant names. Maps are also being prepared showing the distribution of important insects both as to foreign countries and within the United States.

As heretofore the insect-pest survey has acted as clearing house for material furnished the Radio Service on entomological subjects and has supervised the construction of exhibit material to be used by the office of exhibits in the State fairs. The survey has also brought together the plans for the Bureau of Entomology's exhibit at the Chicago Century of Progress World's Fair, and the exhibit displayed in connection with the Inter-American Conference held at the Pan American Union this fall.

MISCELLANEOUS SUBJECTS

The technical studies on insect anatomy, morphology, and physiology are being conducted by R. E. Snodgrass. A considerable number of important papers representing this specialized work have already been published, largely through the channel of technical reports of the Smithsonian Institution. Four additional papers have been completed and will shortly be published. These are: (1) How Insects Fly—a nontechnical account of the mechanism of insect wings, their movement during flight, and a summary of what is known concerning the mechanics of insect flight; (2) The Morphology of the Insect Abdomen—a general review of the structure of the abdomen of insects, including a study of the skeleton and the musculature, with the particular object of obtaining new information to help solve some of the problems involved in the study of the organs of oviposition and copulation; (3) The Abdominal Mechanisms of a Grasshopper—a complete study of the abdominal skeleton and musculature of *Dissosteira carolina* L. giving particular attention to the mechanisms of respiration, circulation, oviposition, and copulation; (4) How Insects Feed—a nontechnical account of the various types of feeding mechanisms of insects, designed for the annual report of the Smithsonian Institution. In addition to these, a very important paper dealing with the morphology and physiology of the alimentary canal of insects is in progress. This paper is to include the morphology, histology, and metamorphosis of the digestive tract in the principal groups of insects, together with a review of all that is known of the digestive processes in insects, the enzymes that have been found in the alimentary canal, and an abstract of the various published opinions on insect digestion and absorption.

The research in bioclimatics (biologic and climatic relations) has been in progress for a number of years under the direction of A. D. Hopkins. This work has now advanced to the stage of making possible an early publication. It represents a study, along entirely original lines, of bioclimatic principles as related to special problems in entomology, ecology, climatology, meteorology, and geographical distribution of plants and animals, but having special relation to insects. It is believed that the utility of this study will be its applicability not only to all types of life but particularly to the determining of the probable geographic range of introduced species within which spread and survival can be predicted. It should also be a useful guide to the determination, for different regions or areas within the United States broadly, and also as to limited or local areas, of the appropriate time for local-control operations, as, for example, the date of planting wheat to protect it from attack by the Hessian fly. A large field of usefulness in this and many other directions is anticipated by Doctor Hopkins.

The study of insect diseases, particularly for the purpose of their utilization in the control of insect pests, was included in the original plan of reorganization when the old Division of Entomology was raised to the bureau status. While the importance of such work and its possibilities have been fully recognized, funds for personnel have not been available to develop this field in any large way. Some early and very important work was completed and published in the study of diseases of the domestic honeybee. In general in this field the bureau's work, however, has been largely the examination and identification of various types of disease which are sent in for study and report. G. F. White is the bureau's specialist in this field.

U. S. GOVERNMENT PRINTING OFFICE: 1930